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THE NITROGEN CONTENT OF SUGARCANE AS INFLUENCED BY MOISTURE AND AGE

George Samuels, Bernardo G. Capó, and Ishver S. Bangdiwala[1]

INTRODUCTION

There is an intimate, dynamic relationship between the moisture content, the age, and the nitrogen content of the various parts of the sugarcane plant. This relationship must be taken into consideration for the precise evaluation of the fertilizer needs of the sugarcane plant by the use of foliar-diagnosis techniques.

The relationship between the factors nitrogen, moisture, and age have been mentioned in the literature, separately, or in various combinations. However, the close association of these three factors has not been thoroughly explored, nor has their bearing on foliar analysis been sufficiently stressed.

Clements has taken these factors into consideration in his work on crop-logging. He used the moisture in the elongating cane sheath as his moisture index (7)[2]; for after numerous analyses of all parts of the cane plant, the sheath was found to be most reflective of the moisture changes in the plant. Clements used the nitrogen content of the elongating cane leaves as his nitrogen index (8). He accounted for the influence of age of the sample by specifying lower levels of both nitrogen and moisture as the age of the plant increased.

Borden touched upon the moisture-nitrogen relationships in cane in his work with the nitrogen fertilization of sugarcane (3). He showed that the moisture content of sugarcane increased as the nitrogen level increased.

Howe (9) in a critical examination of crop logging in Hawaii, mentioned many factors which might influence the leaf-nitrogen content of the cane. He stated that nitrogen is directly related to sheath moisture and inversely related to age. The relationship for leaf nitrogen-sheath moisture-age

[1] Plant Physiologist, Associate Director for Research, and Assistant in Statistics, respectively, of the Agricultural Experiment Station of the University of Puerto Rico, Rio Piedras, P.R. The authors wish to acknowledge the cooperation of Louis Meyer, Research Assistant in Agronomy of the Lajas Substation of the Agricultural Experiment Station, and of Maybin S. Baker, Director, and Calvin S. Burleigh, Agronomist, of the Research Department of Luce & Co., Aguirre, P. R.

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[2] Numbers in parentheses refer to Literature Cited, p. 12.

was developed separately for variety 37-1933 and for a grouping of varieties H.109 and 32-8560. For both varieties, similar curves were obtained for nitrogen as related to age, and straight lines for nitrogen as related to sheath moisture. Three dimensional curves were developed to present the relationship among the three factors: Leaf nitrogen, sheath moisture, and age.

The purpose of this paper is to evaluate critically the nitrogen–moisture–age relationship, and to show how it may be applied quantitatively in establishing a sound foliar-diagnosis program for sugarcane grown in either humid or irrigated areas.

NITROGEN AND MOISTURE

In seeking the relationship between foliar analysis and crop yield in sugarcane, controlled field experiments were carried out by the staff of the Agricultural Experiment Station of the University of Puerto Rico. Yearly data taken from plots which had received the same fertilizer and cultural treatments showed marked variations in leaf-nitrogen values from year to year. An example of this is given in table 1, presenting data from a combined variety-fertilizer experiment carried out at Arecibo on Coloso silty clay (10).

In this experiment, the 125-pound nitrogen-per-acre treatment gave highly significant yields of sugar per acre over the no-nitrogen treatment. In general, for the 5 crops, the use of 125 pounds of nitrogen per acre in excess of 125 pounds of nitrogen per acre did not give additionally significant increases in yield. On this basis, the level of nitrogen in the leaves at the 125-pound nitrogen-per-acre treatment might be selected as the leaf-nitrogen level associated with an optimum application of nitrogen as regards sugar yield per acre. However, it can be seen in table 1 that for the second ratoon, the leaf-nitrogen content was 1.64 percent; for the third ratoon it jumped to 1.76, and for the fourth ratoon it dropped to 1.43. From these values, it is impossible to decide what this leaf-nitrogen level should be. It is obvious that all leaf-nitrogen values are very high for the third, lower for the second, and very low for the fourth ratoon. As the same fertilizer and cultural treatments were used for all crops, these fluctuations were for the most part caused by differences in climate. The climatic factor can be divided into temperature, light, and rainfall. The seasonal variations in temperature and light were not recorded for this experiment and corrections could not be made for these.

The influence of rainfall on the variation of nitrogen in the leaf was determined by using the rainfall data for the area. In figure 1, A, the rainfall for the period from the time of cutting of the previous ratoon crop to the taking of the leaf sample has been plotted against the percentage of nitro-

gen in the leaves. The regression coefficient for the equation of the relationship was significant for the mean of the four varieties. The equation obtained was:

$$Y = 0.96 + 0.021\ X$$

where Y is the percentage of nitrogen in the leaf on a dry-weight basis, and X is the rainfall in inches from the time of cutting the previous ratoon

TABLE 1.—*Nitrogen content as percentage dry weight of leaves of sugarcane*[1] *grown at different nitrogen levels,*[2] *with and without correction for rainfall*

Crop	Results when indicated quantities of nitrogen were applied, in pounds per acre		
	0	125	250
A: *Without correction for rainfall*			
	Percent N	*Percent N*	*Percent N*
Second ratoon	1.43	1.64	1.84
Third ratoon	1.59	1.76	1.83
Fourth ratoon	1.21	1.43	1.43
Mean of 3 crops	1.41	1.61	1.70
B: *Corrected for rainfall*[3]			
	Percent N	*Percent N*	*Percent N*
Second ratoon	1.35	1.56	1.76
Third ratoon	1.38	1.55	1.62
Fourth ratoon	1.36	1.58	1.53
Mean of 3 crops	1.36	1.56	1.64

[1] Mean of 4 varieties: P.O.J. 2878, P.R. 903, M. 275, and M. 317.

[2] All plots received phosphoric acid and potash at rates of 300 lbs. of P_2O_5 and K_2O per acre, respectively.

[3] All nitrogen values corrected to a basis of 20 inches of rainfall for the period from cutting of the previous ratoon crop to the time of leaf sampling. Actual rainfall values in inches were 24, 30, 13 for the corresponding periods of the second, third and fourth ratoons, respectively.

crop to time of sampling. Thus, for every 10 inches of rain falling in the period from the previous harvest to leaf-sampling time, there was a mean increase of 0.21 percent of nitrogen in the leaf sample.

To determine whether rainfall 1 week prior to leaf-sampling time influenced the leaf nitrogen, these factors were plotted graphically (fig. 1, B). The relation obtained was also significant. One inch of rain during the week prior to sampling increased the leaf nitrogen 0.33 percent.

On the basis of 20 inches of rain for the period from the time of planting

or cutting to the time of taking the leaf sample, the nitrogen values of table 1 were adjusted to eliminate the effect of variation in rainfall. The adjusted data are given also in table 1. When the data are compared, it is seen that

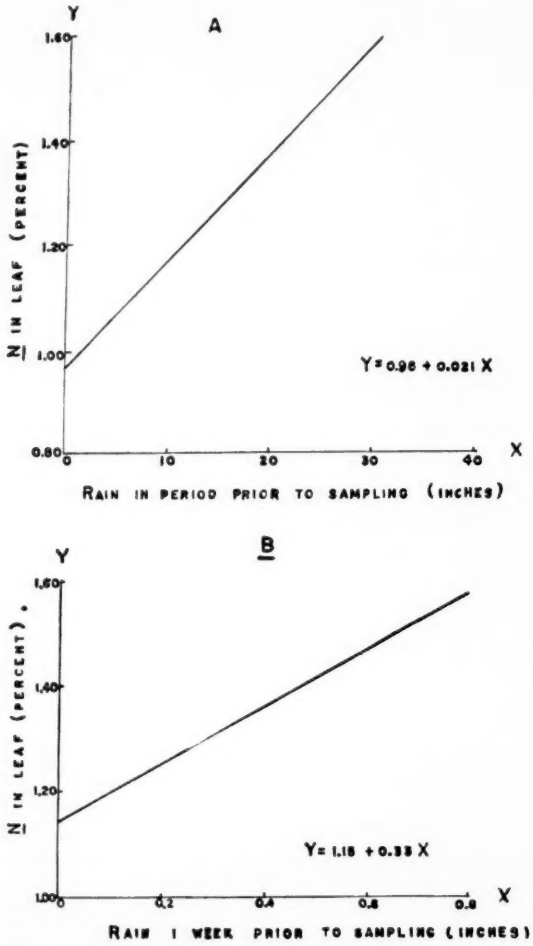

FIG. 1—A. Rainfall during the period from time of cutting previous ratoon crop to the taking of the leaf sample, as compared with percentage nitrogen in the leaf; B, rainfall during the period a week prior to leaf sampling, as compared with percentage nitrogen in the leaf.

the correction for rainfall has adjusted the values for the different years to about the same levels.

It is apparent from these data that increases in rainfall produce higher nitrogen levels in the sugarcane leaf. However, rainfall is but a gross meas-

urement of a more precise factor—the moisture content of the plant. It is obvious that, if more accurate adjustments of the variation of the nitrogen content of the cane sample were to be made, the moisture content of the sample taken must be considered. Unfortunately, there were no data available concerning the moisture content of the leaf samples for which nitrogen had been determined. However, excellent data are available in the literature from the extensive work of R. J. Borden in Hawaii.

Borden, using various nitrogen fertilizer levels on a plant cane and two ratoons of variety 32-8560 attempted to associate leaf-punch nitrogen samples with yields. The values obtained by Borden are given in the first six columns of figures of table 2. It can be seen that, as for the Puerto Rican data, there is a fluctuation of nitrogen with each crop. Because of this fluctuation, especially the low values of the first ratoon, Borden encountered difficulty in selecting a nitrogen level in the leaf which was asso-

TABLE 2.—*The use of cane moisture to correct leaf-blade nitrogen content*[1]

Crop	Moisture in cane when using—			Nitrogen in leaf-punch samples when using—			Nitrogen in leaf-punch samples corrected for moisture, when using—		
	0 N	100 lbs.N	160 lbs.N	0 N	100 lbs.N	160 lbs.N	0 N	100 lbs.N	160 lbs.N
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Plant cane	72.1	74.3	74.3	0.98	1.36	1.46	1.06	1.32	1.42
First ratoon	70.5	72.5	73.6	.90	1.22	1.38	1.07	1.28	1.38
Second ratoon	73.4	75.1	76.2	1.05	1.36	1.53	1.06	1.27	1.38

[1] The data for the percentage moisture in cane and original nitrogen leaf-punch data are from Borden (1 to 3).

ciated with optimum yields. If we use the moisture content of the sugarcane at the time of sampling (sheath-or leaf-moisture values for the three crops were not available) as a means of correcting for nitrogen variations in the leaf, we obtain the values given in the last three columns of table 2. The regression of moisture of the cane on leaf nitrogen was highly significant. The equation obtained for the correction of nitrogen was:

Corrected nitrogen = actual nitrogen − 0.0541 (actual percentage moisture content of cane) + 3.978

The corrected values show very little fluctuation when compared with the original data, and the low values of the first ratoon become comparable to those of the other two crops. The use of moisture for the correction of leaf nitrogen explained 94 percent of the random variation of the leaf-nitrogen values.

In table 3, a comparison is made using another set of data taken from

two plant crops grown under a nitrogen fertilizer test by Borden (4, 5). For these data the correction for moisture was made by using leaf-sheath moisture. The corrected values are given in the last two columns of table 3. Leaf-blade moisture values have been found also to be correlated with the nitrogen content of the leaf, but this relationship is 20 percent less precise than the one for sheath moisture and nitrogen content of blade. The resultant equation of sheath moisture and blade nitrogen was very highly significant; 95 percent of the variation in nitrogen content was explained by

TABLE 3.—*The use of leaf-sheath moisture to correct leaf-blade nitrogen content*[1]

Treatment in pounds of nitrogen per acre	Moisture in leaf sheath in—		Nitrogen in leaf-punch sample in—		Nitrogen in leaf-punch sample corrected for moisture in—	
	1945	1948	1945	1948	1945	1948
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
0	77.4	77.4	1.12	1.08	1.22	1.18
100	79.7	76.7	1.35	1.12	1.23	1.28
160	79.6	77.6	1.46	1.23	1.35	1.31
220	80.4	78.8	1.51	1.32	1.33	1.29

[1] The data for the percentage moisture in leaf sheath and original nitrogen leaf-punch data are from Borden (4, 5).

TABLE 4.—*The variation of sugarcane leaf-sheath moisture for varieties*

Variety	Moisture content of leaf sheath, dry-weight basis	Variety	Moisture content of leaf sheath, dry-weight basis
	Percent		*Percent*
Barbados 37-161	84.36	P.O.J. 2878	85.20
Barbados 34-104	82.55	Mayagüez 336	85.43
Central Aguirre 38-200	82.84		

Least significant difference between means of varieties—
At the 1-percent level: 1.15
At the 5-percent level: 0.84

variations in sheath moisture. The equation obtained for the correction of leaf-blade nitrogen for sheath moisture for the two crops was:

Corrected nitrogen = actual nitrogen − 0.0934 (actual percent moisture in sheath) + 7.330

Preliminary work on leaf-sheath moisture and nitrogen relationships has shown that some varieties exhibit differences in their sheath-moisture content when grown under the same moisture conditions. The sheath-moisture content of several varieties is given in table 4. There are signifi-

cant differences in the sheath-moisture content of some of the varieties. Barbados 34-104 and Central Aguirre 38-200 had lower leaf-sheath moisture values and Mayagüez 336 and P.O.J. 2878 higher values.

NITROGEN AND AGE

In general, as the cane plant grows older, except for the brief initial growing period of a few months, its nitrogen content decreases. When foliar diagnosis is used in humid areas where crop ages at harvest average but 1 year, there is usually but one sampling at a cane age of 3 months.

TABLE 5.—*The influence of sampling age on the nitrogen content of sugarcane leaf-blade samples at different ages (dry-weight basis) for 4 varieties*

Variety and age of sample (months)	Results when indicated quantities of nitrogen were applied, in pounds per acre				Nitrogen difference[1]
	0	62	125	185	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
P.R. 903					
3	1.13	1.60	1.37	1.59	0.46
6	1.29	1.23	1.34	1.57	.28
10	1.38	1.33	1.27	1.39	.01
P.R. 904					
3	1.16	1.49	1.56	1.50	.34
6	1.39	1.44	1.49	1.55	.16
10	1.44	1.39	1.36	1.45	.01
M. 275					
3	1.26	1.20	1.53	1.52	.26
6	1.20	1.28	1.38	1.50	.30
10	1.22	1.28	1.20	1.26	.04
P.O.J. 2961					
3	1.35	1.51	1.62	1.61	.26
6	1.25	1.31	1.49	1.54	.19
10	1.52	1.48	1.45	1.42	.10

[1] Difference between 0 and 185 pounds of nitrogen-per-acre treatment.

The selection of a cane age of 3 months for Puerto Rican foliar diagnosis in humid areas is based upon data obtained at several ages of sampling. The differences obtained are shown in table 5. The greatest difference in leaf-nitrogen content between treatments (0 to 185 pounds of nitrogen per acre) was found at 3 months and the lowest at 10 months.

For cane at crop ages of 18 months to 2 years in irrigated areas, fertilization may be extended for a longer period. In these cases, leaf samples are usually taken at intervals as for the crop-logging system of Clements. However, when leaf samples are taken at various cane ages correction must be made for the influence of age on the nitrogen content of the samples taken.

In figure 2 the influence of age on sheath nitrogen is plotted from data taken on irrigated cane on the southern coast of Puerto Rico. The nitrogen content of the leaf-sheath samples decreased with increasing age. The first six samplings taken when the cane ages ranged from 6 to 10 months showed a significant linear relationship with nitrogen; however, the last three samplings, 7 to 9, did not reveal this tendency. The later samplings showed

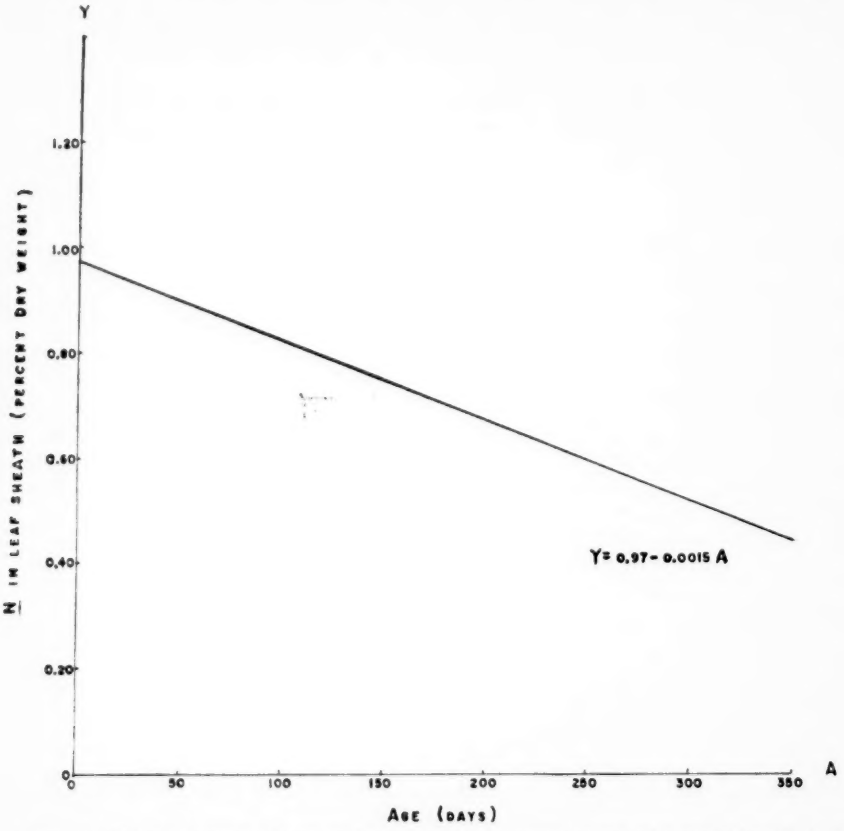

FIG. 2.—The influence of age on leaf-sheath nitrogen (mean of 3 varieties: P.O.J. 2878, B. 34-104, and BH. 10-12 corrected for variety and moisture effects).

a tendency to level off as age increased from 10 to 13 months. A study of Borden's data also revealed that there is a decrease of nitrogen with increase in age up to about an age of 10 to 11 months.

MOISTURE-AGE-NITROGEN

Although we have devoted a section to moisture and nitrogen and one to age and nitrogen, for purposes of clear presentation, in practice these three

factors—moisture, age, and nitrogen, are intimately related and all are operative at the same time. Moisture variations show the greatest influence on nitrogen. However, age is an important factor, if the sampling periods occur in the early portion of the curve where the decrease in nitrogen due to age is rapid, and if the time between samplings is normally greater than 2 months.

TABLE 6.—*Actual vs. adjusted nitrogen content of sugarcane leaf sheaths*[1]

Variety and field location	Nitrogen content of leaf sheath, dry weight-basis		
	Actual value	Adjusted value	Adjustment
	Percent	*Percent*	
P.O.J. 2878			
Destino 14-15	0.53	0.46	−0.07
	.42	.42	0
	.35	.47	+.12
Juana Diaz 56	.54	.47	−.07
	.42	.49	+.07
B 34-104			
Destino 54	.56	.61	+.05
	.66	.64	−.02
Destino 55	.66	.75	+.09
	.93	.71	−.22
BH 10-12			
Carmen 14	.62	.51	−.11
	.43	.43	0
Carmen 15	.52	.51	−.01
	.56	.50	−.06
Paso Seco 55	.68	.58	−.10
	.63	.59	−.04
Paso Seco 56	.59	.49	−.10
	.53	.51	−.02

[1] Calculations based on following equations:

P.O.J. 2878: $Y' = Y + 0.00210\ (A\text{-}250) - 0.0125\ (B\text{-}84.99)$

B 34-104 : $Y' = Y + 0.00119\ (A\text{-}219) - 0.0820\ (B\text{-}86.17)$

BH 10-12 : $Y' = Y + 0.00063\ (A\text{-}258) - 0.0230\ (B\text{-}81.51)$

where Y' is the adjusted leaf-sheath nitrogen, Y the actual leaf-sheath nitrogen, A the age of sample in days, and B the percentage moisture content of the leaf-sheath sample.

It may be felt that the evaluation of moisture and age only on nitrogen does not include all of the main factors which might influence the nitrogen content in the leaf sample. However, a study of data taken from cane growing on the irrigated southern coast of Puerto Rico, revealed that the variation of age and moisture with nitrogen explained over 95 percent of the random nitrogen variation. This left but 5-percent residual error to be

attributed to such sources as soil and temperature differences. Clements, in a study of the factors influencing leaf nitrogen (6), found that sheath moisture showed the greatest dominant influence, and then age, maximum and minimum temperatures, and soil moisture also had some influence, but the latter three not nearly as much as did sheath moisture and age.

The influence of moisture and age on nitrogen in the cane plant is so dominant that we may use these two factors to adjust the nitrogen content of the tissue sample. With the equation obtained from the study of age and moisture on leaf-sheath nitrogen in irrigated cane from the southern coast of Puerto Rico, leaf-sheath nitrogen was adjusted using only sheath-moisture and age data. This information compared with actual values is given in table 6. It can be seen that there is very good consistency among the adjusted values.

This again serves to show that a proper evaluation of moisture and age in foliar-diagnosis work with sugarcane will allow the worker to obtain nitrogen values which can safely be used to decide whether a deficiency of nitrogen exists and the cane should be fertilized. When these nitrogen values are corrected for moisture and age, most of the variation to be encountered is eliminated, and a true picture of the nitrogen status of the cane plant can be obtained.

SUMMARY

Moisture and age have a dominant influence on the nitrogen content of the sugarcane plant. A study of these factors revealed the following:

1. The nitrogen content of the leaf sample varied from year to year, despite constant cultural and fertilizer treatments.

2. A correction of nitrogen content for moisture eliminated the majority of the fluctuation of nitrogen in the leaf samples.

3. In most cases, leaf-sheath moisture and leaf-blade moisture gave the best correction for nitrogen variation, but rainfall variation could be used as a correction factor.

4. The nitrogen content of the leaf sample increased with increasing moisture content of the tissue; this increase was linear.

5. The nitrogen content of the leaf tissue decreased with increasing age of the cane plant. Thus a decrease in nitrogen is approximately linear to an age of about 10 to 11 months for sugarcane in Puerto Rico. After 11 months the decrease tends to level off. This relationship was also observed for Hawaiian data.

6. The factors of moisture and age appear to be the most dominant in influencing the nitrogen content of the cane-leaf sample. A correction for

both moisture and age in the leaf samples taken, in many cases explained over 90 percent of the variation of the nitrogen in the sample.

7. Adjusted leaf-sheath nitrogen values were obtained from an equation using sheath moisture and age of sample. The adjusted values were in very close agreement.

RESUMEN

Los propósitos principales de este trabajo han sido: evaluar críticamente la relación entre las concentraciones de nitrógeno y agua del tejido vegetal de la caña de azúcar, y demostrar cómo se puede usar esta relación cuantitativa para determinar los requisitos del abonamiento de esta cosecha, mediante el análisis químico de la hoja.

Los datos que se presentan en este artículo demuestran que la concentración del nitrógeno en la hoja de la caña de azúcar guarda estrecha relación con la concentración de agua en la hoja. Esta concentración de nitrógeno puede usarse como un índice para determinar el grado de suficiencia o deficiencia, respecto a la alimentación de la caña, en cuanto a este elemento nutritivo.

El conocimiento que se tenga del contenido de agua en la hoja para corregir el análisis de nitrógeno, será de ayuda para hacer más exacto este sistema de análisis, de modo que se pueda decidir si es o no conveniente hacer a la cosecha una aplicación de abono nitrogenado, según lo demuestre el análisis de las hojas.

De este trabajo se pueden derivar las siguientes conclusiones:

1. El ajuste de la concentración de nitrógeno en las hojas de la caña, verificada a base de las variaciones del contenido de agua de las hojas analizadas, elimina la mayor parte de la variación casual que ocurre cuando se analizan distintas muestras de hojas representativas de una determinada serie de condiciones de crecimiento.

2. Cuando se hace uso de un factor tan sencillo como es la lluvia, desde la cosecha previa hasta que se toma la muestra, y aún la de la semana anterior a la toma de ésta, se puede corregir el contenido de nitrógeno, aunque no con la exactitud que puede hacerse cuando se determina la humedad de la misma muestra que se analiza para nitrógeno.

3. La concentración de nitrógeno de la hoja de la caña tiende a aumentar en forma de relación rectilínea, según aumenta la humedad en el tejido.

4. La concentración de nitrógeno, también, es afectada por la edad del tejido, pero si se toman las muestras de hojas cuando las plantas tienen una edad uniforme, es posible eliminar la influencia de este factor. Además, se pueden fijar con precisión los límites críticos de la concentración de nitrógeno en la hoja, a distintas edades de la planta.

5. Los ajustes hechos a base de la edad y contenido de humedad eliminaron más del 90 por ciento de la variación casual del nitrógeno en las muestras de cada una de distintas variedades de caña cultivadas bajo condiciones similares de clima, suelo y manejo en el campo.

LITERATURE

1. Borden, R. J., A search for guidance in the nitrogen fertilization of the sugarcane crop, Pt. I, The plant crop, *Hawaiian Planters' Record,* **46** 191–233 1942.
2. Borden, R. J., Pt. II, The first ratoon crop, *Hawaiian Planters' Record,* **48** 271–306 1948.
3. Borden, R. J., Pt. III, The second ratoon crop, *Hawaiian Planters' Record,* **50** 161–200 1946.
4. Borden, R. J., The effects of nitrogen fertilization upon the yield and composition of sugarcane, *Hawaiian Planters' Record,* **49** 259–312 1945.
5. Borden, R. J., Nitrogen effects upon yield and composition of sugarcane, *Hawaiian Planters' Record,* **52** 1–51 1948.
6. Clements, H. F., Environmental influences on the growth of sugarcane, Mineral Nutrition of Plants, pages 451–469, The Univ. of Wis. Press., 1951.
7. Clements, H. F. and Kubota, T., The primary index, its meaning and application to crop management with special reference to sugarcane, *Hawaiian Planters' Record,* **47** 257–97 1943.
8. Clements, H. F. and Moreguchi, S., The nitrogen index and certain quantitative field aspects, *Hawaiian Planters' Record,* **46** 163–90, 1942.
9. Howe, G. L., A study of crop logging at Ewer and Kohala, *Hawaiian Sugar Technologists Report,* Tenth Annual meeting, pp. 3–6, 1951.
10. Samuels, G. and Landrau, P. Jr., The response of sugarcane to fertilizers, I, The Arecibo cycle, 1944–1950, *J. Agr. Univ. P.R.,* **36** 203–29 1952.

EFFECT OF MOSAIC ON THE YIELD OF SUGARCANE VARIETY B. 34-104

P. González Ríos and J. Adsuar[1]

INTRODUCTION

Since the importation into the Island and planting on large scale of mosaic-resistant P.O.J. sugarcane varieties, and the development and production of the Puerto Rico and Mayagüez resistant sugarcane seedlings by the Island and Federal Experiment Stations, respectively, sugarcane mosaic has been practically under control in Puerto Rico. This magnificent accomplishment should not obscure the fact that we are, so to speak, living with the disease, and that the virus is still present in the Island ready to strike with frightful consequences whenever an opportunity is offered in the form of a susceptible variety, no matter how good its other agronomic qualities might be.

The recent introduction of the Barbados seedlings, B. 34-104 and B. 37-161, clearly demonstrates this. Because of their excellent agronomic qualities these two canes, especially B. 34-104, have been increasing in popularity with the growers of the Island. According to reports from Jamaica, B. 34-104 is unaffected by the strain of mosaic found there. Depending on that information our growers have extensively propagated this variety. Preliminary observations, however, indicated that both varieties, especially B. 34-104, were highly susceptible to the sugarcane mosaic virus present in Puerto Rico. But this now generally admitted fact has not yet tempered the enthusiasm of many growers who still claim, not only that B. 34-104 recovers from the mosaic, but that, even when infected, it yields more sugar per acre than many of the standard varieties grown in the Island.

The results obtained with these canes at the Station during the past two years have failed to substantiate these claims. Cane stools of both varieties which were infected in the laboratory and transplanted to the field, were carefully observed for a period of 3 years. No sign of recovery appeared either in the plant cane or in the ratoons of B. 34-104. Variety B. 37-161 showed a high degree of tolerance but did not seem to recover from mosaic.

The purpose of this paper is to present the results obtained from a field trial to determine the effect of cane mosaic on the sugar yield of B. 34-104.

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MATERIALS AND METHODS

Shortly after the sugarcane grinding season of 1950 was over an inspection was made of the fields planted to the variety B. 34-104 in the Yabucoa, Humacao, and Caguas districts, with the object of estimating the degree of mosaic infestation to which it was subject in these areas. It was observed that mosaic was spreading here very rapidly, in fact, as fast as new plantings were made with seed obtained from seedbeds with slight to medium infestation. Counts as high as 50 percent were obtained in the Caguas district 4 months after the 1950 spring plantings were made. In Humacao and Yabucoa the same situation was encountered, the percentage of infection observed being still higher in the first and second ratoons. It was the general belief of many farmers in these areas that the mosaic attacking B. 34-104 did not affect the yield of the variety and even that it recovered from the disease. Close observations made by the Plant Breeding and the Plant Pathology Departments indicated that this was not the case, and therefore, it was decided to set up an experiment at the Agricultural Experiment Station in Río Piedras.

The mosaic-infected material for planting the experiment was obtained from the Yabucoa area. The disease-free material was obtained from the Isabela Substation, where B. 34-104 was inspected and found to be free from mosaic. As checks for comparison two highly mosaic-resistant varieties were used: P.O.J. 2878 and P.R. 902.

The site for the experiment was selected on a Vega Baja silty clay soil type. Two plowings and two harrowings were given to the land during the month of May 1950, before planting. The field was furrowed wis a double moldboard plow, making furrows 4 feet apart and to a depth of about 14 inches. Small ditches (*sangrías*) were opened to insure appropriate drainage and the plots were marked out.

Each plot consisted of four furrows 18 feet long, equivalent to an area of one one-hundred-fiftieth of an acre. A randomized complete block design was used in laying out the experiment. Each treatment was replicated 12 times. Twenty seed-cane cuttings, each with three eyes, were planted in each furrow using a total of 80 seed pieces per plot. Two rows of canes of the variety P.O.J. 2878 were planted around each individual plot to serve as a buffer and to protect against secondary infection from the mosaic-infected plots of B. 34-104.

The plots were planted on June 26, 1950. A 14-4-10 fertilizer was used in a single application 1 month after planting, at the rate of 1,000 pounds per acre. Three weedings were made during the early growing season and the plots were harvested on June 6, 1951, when the crop was 11½ months old.

The experiment was carried on for another year in order to observe the

TABLE 1.—*Production of: Cane per acre; available sugar percent in the cane; sugar yield per acre; and sugar per month of growth per acre for healthy and mosaic-infected sugarcane*

No.	Treatment	Tons of cane per acre			Available 96° sugar percent cane			Sugar production in cwt. per acre			Sugar production per month of growth in cwt. per acre		
		Plant	Ratoon	Combined crops	Plant	Ratoon	Combined crops (average)	Plant	Ratoon	Combined crops	Plant 11.5 months	Ratoon 12 months	Combined crops (average)
1	B. 34-104 healthy	50.92	61.25	112	11.78	10.79	11.29	120	132	252	10.43	11.00	10.72
2	P.O.J. 2878	48.25	41.33	90	12.44	11.97	12.20	120	99	219	10.43	8.25	9.34
3	B. 34-104 mosaic infested	41.33	42.00	83	10.65	9.17	9.91	88	77	165	7.65	6.41	7.03
4	P.R. 902	36.50	25.83	62	9.30	10.84	10.07	68	56	124	5.91	4.67	5.29
Least significant differences for comparison at:													
5-percent point				8						21			0.89
1-percent point				11						28			1.19

effect of mosaic on the ratoon crop. The trash was aligned in alternate rows and cultivation practiced in the clean banks. Some replanting had to be done on the diseased plots of B. 34-104, while very little was required by either healthy or check plots. A single application of fertilizer was made to the ratoon crop at a rate of 800 pounds per acre of sulfate of ammonia. Two weedings were necessary to keep the cane clean of weeds. The plots were harvested for the second time on June 2, 1952, when the ratoon crop was 12 months old.

Periodical counts were made on the healthy plots for diseased stools caused by secondary infections both on the plant cane during the first year and the ratoon cane during the second year.

In each harvesting the plots were cut and the cane was weighed right in the field by using a portable weighing outfit. Ten cane stalks cut at full length were selected at random from each plot weighed, ground in a Squier hydraulic mill, and the extracted juice weighed and analyzed to determine the available sugar content.

EXPERIMENTAL DATA

Quantitative data on the effect of sugarcane mosaic on the production of cane stalks and yield of sugar are given in table 1. The production of cane is given in tons of 2,000 pounds per acre. The yield is given in hundredweights of sugar of 96° polarization and the available sugar in the cane as available 96° sugar percent cane.

DISCUSSION

The mosaic-infected plots of B. 34-104 remained 100-percent infected throughout the 2-year duration of the experiment. Not a single case of recovery was noticed in any of the diseased plots. During the first year only one stool was observed with mosaic in the healthy plots. Stool-counting inspections were performed every month up to the tenth month of growth when the cane stalks were too entangled to permit entering the plots.

The statistical analysis of the results shows that the cane yield of the healthy B. 34-104 was 29-percent superior to that of B. 34-104 with mosaic in the plant-cane crop, and 32-percent higher in the ratoon crop. The average available sugar content of the cane in the healthy B. 34-104 was 11.29 percent against 9.91 percent for the diseased cane, or a deficiency of 12.23 for the latter in the total sugar content (table 1).

The production of sugar 96° polarization by the healthy B. 34-104 when harvested as plant cane during the first year was 26.7 percent higher than the production by the diseased cane, and 41.7 percent higher when cut as a ratoon crop during the second year. These same percentages were obtained in calculating the per month production of sugar per acre for the healthy and the infected cane (table 1). It has been clearly demonstrated

that there is a great reduction in the sugar content of the diseased plants in the ratoon stage as compared with the plant crop. It was also shown that the difference in sugar content percent cane between the healthy and diseased canes was only 3 percent, while the difference in sugar production in hundredweights per acre was 15 percent, or five times as much.

If the variety B. 34-104 could be maintained free of mosaic it would produce a little more total sugar per acre than P.O.J. 2878 in the Río Piedras area, but with a greater tonnage to be cut and hauled and, in the long run, it would prove to be less profitable than P.O.J. 2878.

Variety P.R. 902 proved unadapted to Río Piedras conditions. This checks with the results of previous variety trials.

SUMMARY

Many farmers in Puerto Rico believe that the sugarcane variety B. 34104, although susceptible to mosaic, can produce more sugar than the current known commercial varieties, and that this variety recovers from the disease. Preliminary investigations by technical staff members of the Agricultural Experiment Station did not confirm this. A controlled experiment was carried out and the following conclusions were drawn:

1. Once the canes of variety B. 34-104 are infected with the common sugarcane mosaic prevailing in the Island they do not recover from the disease, and infected seed produces diseased plants.

2. There was a reduction of 29 percent in tonnage production in the plant cane crop and of 32 percent in the first ratoon crop attributable to the disease.

3. There was a difference of 26.7 percent in the production of 96° sugar per acre in the plant cane crop and of 41.7 percent in the first ratoon crop between the healthy and infected canes.

4. If B. 34-104 could be maintained free from mosaic it would produce about the same quantity of sugar as P.O.J. 2878, but a greater tonnage would have to be handled and processed, and profits would be lower.

RESUMEN

Los agricultores de caña en Puerto Rico han estado creyendo que la variedad B. 34-104, a pesar de ser susceptible al mosaico, puede producir mayor cantidad de azúcar que cualquiera de las variedades comerciales corrientes cultivadas en la Isla y que también hasta puede sanar de la enfermedad. En investigaciones preliminares llevadas a cabo por miembros del personal técnico de la Estación Experimental se observó que esta creencia no está justificada. Al efecto, se llevó a cabo un experimento controlado, del cual se derivaron las conclusiones siguientes:

1. Una vez que las cañas de la variedad B. 34-104 adquieren la infección

con el mosaico común prevaleciente en la Isla no vuelven a recobrar de la enfermedad; además, cañas enfermas usadas como semilla producen plantas enfermas.

2. Se obtuvieron diferencias en tonelaje de 29 porciento en plantilla y de 32 porciento en retoño entre la variedad sana y la enferma.

3. Las reducciones obtenidas en la producción de azúcar por cuerda debidas a la enfermedad fueron de 26.7 porciento en la plantilla y de 41.7 en el retoño.

4. La variedad B. 34-104 mantenida libre de mosaico produce tanta azúcar como la variedad P.O.J.-2878, pero produce un mayor tonelaje.

EFFECT OF CHLOROTIC STREAK ON THE YIELD OF SUGARCANE

P. Landrau, Jr. and J. Adsuar[1]

INTRODUCTION

Chlorotic streak, a virus disease of sugarcane, is of considerable potential economic importance since it has been observed to cause a marked reduction in yields of cane and in the germination and tillering of plant cane.

During the 1932 Conference of the International Society of Sugarcane Technologists, Willbrink, Bell and Martin reported having observed the disease in Puerto Rico, and each recognized it as being identical with a disease occurring in Java, Australia, and Hawaii. In 1946, Adsuar (2)[2] definitely demonstrated its presence in Puerto Rico on the sugarcane variety P.O.J. 2878.

In 1942 Abbott and Ingram (3) proved that *Draeculacephala portola* transmitted chlorotic streak in Louisiana. *D. portola* has not been reported in Puerto Rico where chlorotic streak apparently spreads under natural conditions, although other members of the genus *Draeculacephala* are present.

DIAGNOSIS AND PREVALENCE OF STREAK

The most reliable diagnostic symptom of the disease is the appearance on the leaves of chlorotic streaks (fig. 1) which vary in length from a few millimeters to nearly the entire length of the leaf. The streaks are distinguished from others occurring on sugarcane leaves by their broken, wavy, irregular margins. Apparently chlorotic streak is not a completely systemic disease, nor do all the aerial parts of the plant appear to be affected. Abbott (4) claimed that complete recovery might occur even after the disease had developed.

The insidious nature of the disease makes diagnosis difficult for the untrained person, and, therefore, the damage caused by the virus is not so plainly seen. Although no systematic survey of the extent of the chlorotic streak has been undertaken in Puerto Rico, preliminary observations have indicated that the disease is widely prevalent in the northern, eastern, and

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[2] Numbers in parentheses refer to Literature Cited, pp. 26–7.

central cane regions of the Island. Possibly because P.O.J. 2878 is the variety most widely planted in Puerto Rico, the majority of the affected canes belong to this variety, although the disease has been found on other varieties as well.

Considering both the importance and extent of chlorotic streak, as well as the fact that the susceptible variety P.O.J. 2878 covers approximately

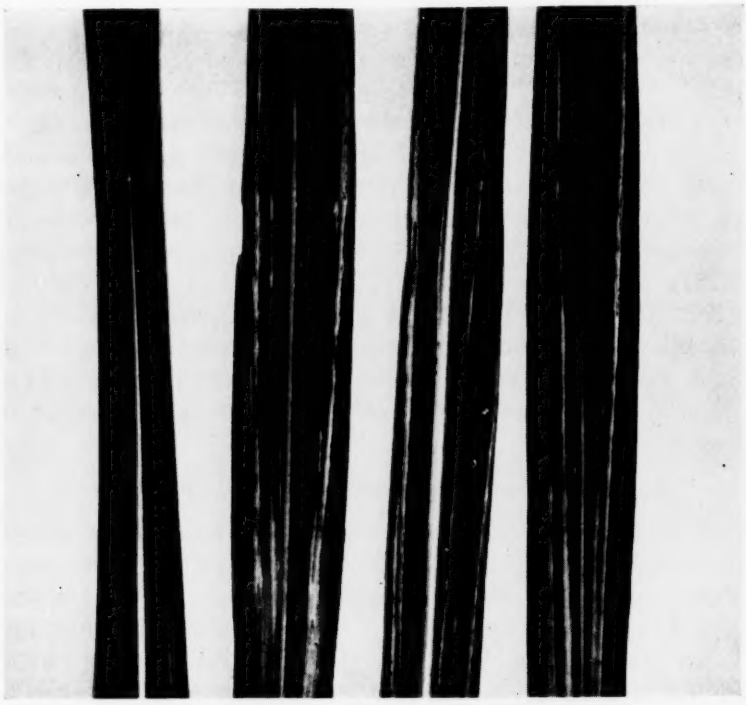

FIG. 1—Leaves of sugarcane showing chlorotic streak, as compared with a healthy leaf at the extreme left.

65 percent of the cane land planted in Puero Rico (8), a field experiment was performed to determine to what extent the plant cane and the successive ratoon crops were affected by this disease, especially as regarded yield and sugar content.

EXPERIMENTAL PROCEDURE

With this end in view, a field experiment was set up in May 1949, at Solís Farm, Río Piedras, on a Vega Alta clay loam. This area is located on the northern part of the Island and has a mean annual rainfall of about 72 inches. Results with the following were compared: (A) Infected seed,

(B) noninfected seed, (C) infected-treated seed, and (D) noninfected-treated seed.

Seed treatment consisted of immersing the seed in hot water (52°C.) for 20 minutes and then submerging them in cold water until cool. Figure 2 presents the equipment used for heating the water and soaking the infected material.

The equipment for treating the seed, designed at the Agricultural Experiment Station, consisted of two empty 50-gallon drums, one of them

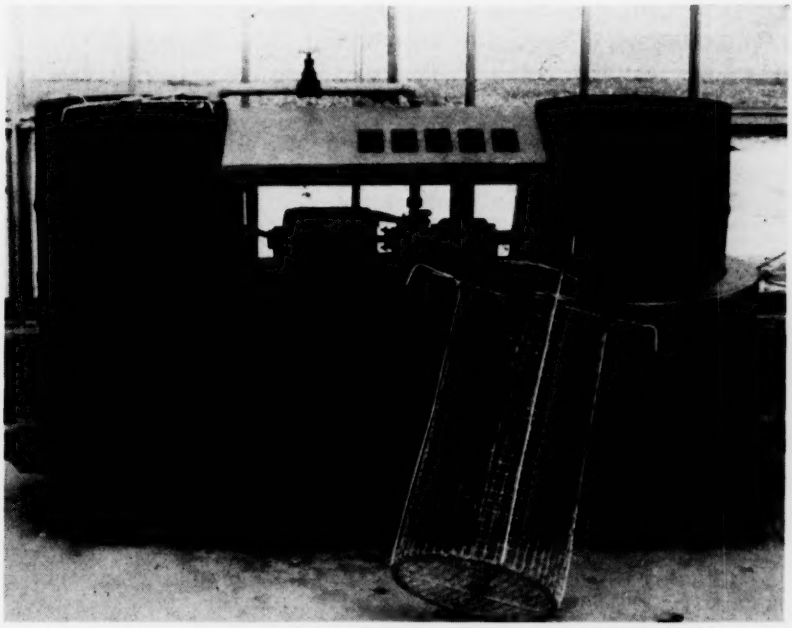

FIG. 2—Equipment used for heat-treating sugarcane seed pieces.

being heated by four 2,000-watt heating coils. The resistances were connected to a switchboard with 4 switches, one to each resistance. A pump was used to keep the water in continuous movement from one drum to the other. Cylindrical baskets were made of ½-inch-mesh wire, 32 inches in height and 15 inches in diameter. In the center of each basket there was another mesh-wire cylinder, 1 inch in diameter and 32 inches in height for the thermometer. The basket was suspended in the drum by four ¼-inch solid wires bent at the ends at a 90° angle. The basket was reinforced on the ends and bottom by a ¼-inch solid wire.

Before treating the seeds both drums were filled with water to a height about 6 inches from the top, and the four heating-coil switches were turned

on. When the water reached a temperature of 56° to 60°C. a valve was opened and the hot water was circulated by means of the pump. When the circulating water reached 52°C. in the two drums, two of the heating units were shut off. The baskets were filled with sugarcane seed pieces and submerged for 20 minutes. They were then placed in cold water to prevent further heat damage to the growing buds.

The field experiment was designed as a randomized block lay-out with 10 replications for each treatment. The plots were 18 feet wide by 24 feet long, or approximately one one-hundredth of an acre in area. The sugarcane planting material consisted of 3-eye seed pieces which were laid in the bottom of the furrow and covered with soil. Each plot had four furrows, 4½ feet apart. Twenty-four seed pieces were planted per furrow at a rate of approximately 10,000 per acre. The propagating material was carefully selected from diseased and sound canes in accordance with the schedule previously mentioned.

Planting, cultivation, and fertilizer applications were carried out in accordance with procedures usually followed by farmers throughout the Río Piedras area.

Percentage infestation counts were made yearly using all cane tops of the two middle rows from each plot. Each crop was harvested at 12 months of age.

EXPERIMENTAL RESULTS

The results with a plant cane and two ratoon crops are presented in tables 1 to 5. The infection caused a significant reduction in the yield of cane per acre. Noninfected, infected-treated, and noninfected-treated seed produced higher tonnages of cane than the infected-nontreated seed. These differences in cane tonnages were significant at the 1-percent level (table 1). Noninfected seed produced significantly higher yields at the 1-percent level than infected seed in the plant cane and first ratoon crops. No significant differences were observed in the second ratoon crop. The results of the mean of the three crops followed the pattern of the plant and first ratoon crops.

Table 2 shows the mean yields of available 96° sugar per acre. The results followed the same general trend as those for cane yields. Noninfected, infected-treated and noninfected-treated seed produced yields statistically higher at the 1-percent level than did infected seed, for the plant cane and first ratoon crops. The second ratoon crop failed to give significant results. In table 3 the percentage increases in sugar yields caused by treatments are shown. There were large (approximately 45 percent) increases in yields when noninfected seed were used. Increases of approximately 28 and 35 percent, respectively, were registered for the first two crops when the infected seed were treated with hot water.

TABLE 1.—*Mean yields of cane per acre for a plant cane and two ratoon crops, as affected by seed infection with chlorotic streak, treated and untreated*

Symbol	Seed used	Mean yields of cane per acre for—			Mean of 3 crops
		Plant cane 1949–50	First ratoon 1950–51	Second ratoon 1951–52	
		Tons	*Tons*	*Tons*	*Tons*
A	Infected	33	25	45	34
B	Noninfected	46	33	48	42
C	Infected-treated	41	34	48	41
D	Noninfected-treated	40	33	49	41
Minimum significant differences between the means of two treatments at:					
5-percent level		3.57	3.45	4.69	3.38
1-percent level		4.82	4.66	6.34	4.56

TABLE 2.—*Mean yields of available 96° sugar per acre for a plant cane and two ratoon crops, as affected by seed infection with chlorotic streak, treated and untreated*

Symbol	Seed used	Mean available 96° sugar yields per acre for—			Mean of 3 crops
		Plant cane 1949–50	First ratoon 1950–51	Second ratoon 1951–52	
		Hundred-weights	*Hundred-weights*	*Hundred-weights*	*Hundred-weights*
A	Infected	76	68	109	84
B	Noninfected	110	89	115	105
C	Infected-treated	97	92	119	103
D	Noninfected-treated	92	89	115	99
Minimum significant difference between the means of two treatments at:					
5-percent level		9.95	9.94	13.89	9.52
1-percent level		13.44	13.39	18.76	12.86

TABLE 3.—*Percentage increase in yield of sugar per acre of a plant cane and two ratoon crops, as affected by seed infection with chlorotic streak, treated and untreated*

Treatments compared	Increase in yield[1] for—		
	Plant cane	First ratoon	Second ratoon
	Percent	*Percent*	*Percent*
Noninfected vs. infected	44.74	30.88	5.50
Infected-treated vs. infected	27.63	35.29	9.17
Noninfected-treated vs. infected	21.05	30.88	5.50
Noninfected-treated vs. noninfected	−16.36	0	0
Infected-treated vs. noninfected	−11.82	−3.37	3.47

[1] Based on available 96° sugar per acre.

The mean available 96° sugar percent cane for all crops was not affected by the infection (table 4). The first ratoon crops gave the highest available 96° sugar percent cane, but it was about the same as for the other two crops, and no significant differences were observed between treatments.

Data on percentage infestation with chlorotic streak of a plant cane

TABLE 4.—*Mean available 96° sugar percent cane for a plant cane and two ratoon crops, as affected by seed infection with chlorotic streak, treated and untreated*

Symbol	Seed used	Mean available 96° sugar per acre for—			Mean of 3 crops
		Plant cane 1949–50	First ratoon 1950–51	Second ratoon 1951–52	
		Percent	*Percent*	*Percent*	*Percent*
A	Infected	11.39	13.44	12.17	12.33
B	Noninfected	11.89	13.51	12.01	12.47
C	Infected-treated	12.00	13.55	12.26	12.61
D	Noninfected-treated	11.46	13.48	11.66	12.19
Minimum significant difference needed between the means of two treatments at:					
5-percent level		0.60	0.43	0.73	0.43
1-percent level		.81	.59	.98	.58

TABLE 5.—*Percentage infection with chlorotic streak of a plant cane and two ratoon crops, as affected by seed infection with chlorotic streak, treated and untreated*

Symbol	Seed used	Infection with chlorotic streak in—			Mean of 3 crops
		Plant cane 1949–50	First ratoon 1950–51	Second ratoon 1951–52	
A	Infected	51	41	10	34
B	Noninfected	20	26	9	18
C	Infected-treated	11	18	5	12
D	Noninfected-treated	18	14	4	12
Minimum significant difference needed between the means of two treatments at:					
5-percent level		10.08	9.54	4.78	4.79
1-percent level		13.61	12.89	6.45	6.47

and two ratoon crops are presented in table 5. The plants resulting from infected, nontreated seed pieces were severely attacked by chlorotic streak The incidence of the disease in a plant cane developed from noninfected seed was considerably lower.

The hot-water treatment was very effective in reducing the rate of infection. In the second ratoon crop the incidence of the disease was rather

low for all treatments, probably because of unfavorable conditions for the development and manifestation of the disease symptoms.

DISCUSSION

Chlorotic streak, an infectious virus disease of sugarcane that spreads easily via cuttings, is largely confined to the humid section of the Island, being found much less frequently in the drier areas. Abbott, in Louisiana (1), has observed that excessive soil moisture accentuates the incidence of the disease.

Very little is known concerning the susceptibility of different varieties to the disease; however, field observations have shown that the sugarcane variety P.O.J 2878, which comprises about 65 percent of the sugarcane grown in Puerto Rico, is highly susceptible. Furthermore, some of the varieties originating in Barbados and Puerto Rico have shown marked susceptibility to the disease. The Barbados 34-104 and 37-161, the P.R. 902 and 905, and the M. 336 are all particularly susceptible under certain climatic conditions.

Several investigators claim that the low or high incidence of the disease may be the result of nutritional disturbances (1–7). In some varieties applications of nitrogenous fertilizer to young plants have been observed to increase the number of leaf symptoms; however, heavy applications of nitrogen at frequent intervals during the life of the plant produced a high degree of recovery in some sugarcane varieties (1).

Chlorotic streak is sometimes difficult to detect symptomatically. The results for the first two crops indicate that a 20- to 26-percent infection occurred in plants developed from noninfected seed. This infection may have occurred either because the presence of chlorotic streak virus was not detected in some of the apparently healthy plant matrial used, or because some of the noninfected material used became infected in the field. Several investigators (5, 6, 9) have shown that the hot-water treatment used gives complete control of the disease in infected stock. The development of the disease in the cane produced from the treated seed pieces (treatments C and D) after planting suggests that reinfection of the treated seed pieces occurs in the field.

In general, the results indicate that the damage caused by chlorotic streak disease can be effectively prevented by immersing the seed pieces in hot water (at 52°C.) for a 20-minute period prior to planting. As shown in tables 1 and 2, it is not advantageous to treat noninfected seed pieces; in fact, yield reductions were then observed in the plant crop.

SUMMARY

A field experiment was carried out at Río Piedras to determine the extent to which sugarcane yields are reduced by chlorotic streak.

Results with the following were compared: (A) Infected seed, (B) noninfected seed, (C) infected-treated seed, (D) noninfected-treated seed. Cane developed from noninfected sugarcane seed pieces produced significantly higher yields than that developed from infected stock.

Immersion in hot water (52°C. for 20 minutes) significantly reduced the incidence of the disease and increased the yields of cane and of sugar. An increase of about 45 percent in sugar production was obtained by planting noninfected healthy sugarcane seed pieces instead of infected nontreated seed pieces.

The proper selection of good seed pieces free from infection with chlorotic streak will give higher yields of cane without the expense of treating the seed pieces to control the infection.

RESUMEN

En la Estación Experimental Agrícola, en Río Piedras, se llevó a cabo un experimento con el objeto de determinar hasta qué punto la enfermedad, llamada raya clorótica, puede reducir los rendimientos de la cana de azúcar.

Se compararon los resultados de los siguientes tratamientos: (A) Semilla infectada, (B) semilla sana, (C) semilla infectada tratada, (D) semilla sana tratada. La caña desarrollada de pedazos de semilla sana, produjo rendimientos que fueron significativamente mayores que la desarrollada de pedazos de semilla infectada.

La inmersión de la semilla en agua caliente (52°C. por 20 minutos), redujo significativamente la incidencia de la enfermedad y aumentó los rendimientos de la caña y del azúcar en la caña. Se logró un aumento, en un 45 por ciento, en los rendimientos de azúcar, cuando se sembró semilla sana, al compararse con la producción de los tratamientos con semilla infectada que no se trató.

Los resultados del experimento señalan el hecho de que si se selecciona adecuadamente la semilla para las siembras en el campo, de modo que esté libre de la raya clorótica, no sólo se consiguen mayores rendimientos de caña, si que también se evitan los gastos de tratar la semilla para controlar la infección.

LITERATURE CITED

1. Abbott, E. V., Influence of certain environmental conditions on chlorotic streak of sugarcane, *Phytopath.* **37** 162–73 1947.
2. Adsuar, José, Chlorotic streak disease of sugarcane in Puerto Rico, Agric. Expt. Sta. Tech. Paper No. 3, 12 pp., August 1946.
3. Abbott, E. V. and J. W. Ingram, Transmission of chlorotic streak of sugarcane by the leaf hopper *Draeculacephala portola*, *Phytopath.* **32** 99–100 1942.

4. Abbott, E. V. and Sass, E. John, Pathological Histology of sugarcane affected with chlorotic streak, *J. Agri. Res.*, **70**(6) 201–07 1945.
5. Beel, A. F., *Queensland Agr. J.*, **40** 460 1933.
6. Martin, J. P., *Hawaii Planter's Record*, **34** 375 1930.
7. Martin, J. P., Rept. of the 56th. Ann. meeting of the Hawaiian Sugar Planters Assn., p. 30, 1937.
8. Silva E. and Serra, G., Census of sugarcane varieties grown in Puerto Rico for the 1949 crop, mimeographed E.A. 11, Department of Economics, Agric. Exp. Sta., Univ. P.R., Feb. 1950.
9. Wilbrink, G., *Arch Suikerind Netherland Sch. Indii* **31** 1 1923.

FACTORS AFFECTING THE SUCROSE CONTENT OF SUGARCANE: III, VARIETIES

M. A. Lugo-López, G. Samuels, and F. Méndez[1]

INTRODUCTION

It has been long recognized that there are significant differences among the sucrose yields of sugarcane varieties at harvesttime. All other ecological, biological, and cultural factors being constant, certain varieties normally produce more sucrose than others. The importance of superior sucrose-producing sugarcane varieties can hardly be ignored; when there are no significant differences between the mean sugar or green millable cane yields of two or more varieties, the one that can accumulate the most sucrose by harvesttime will naturally give the best returns to the grower, other factors being equal. In a 40-ton-per-acre crop of sugarcane the monetary difference between a cane variety yielding 12 percent of available 96° sugar and another yielding 13 percent may amount to $40 or $50 per acre, without the added expense of dealing with a heavier cane tonnage.

By far, most of the progress attained in the sugarcane industry in Puerto Rico, as well as in other sugarcane-producing areas, can be traced back to the introduction, breeding, and selection of superior cane varieties. A program of this nature cannot be limited to such factors as sucrose, tonnage, and sugar yields. Other factors must be considered also such as stooling, tillering, growth habit, vigor, quickness of closing up, covering the ground, and smothering the weeds, presence or absence of prickly hairs, shedding of dry leaves, disease resistance, and other characteristics. In spite of all these factors that the plant breeder and the field agronomist must consider, sucrose accumulation at harvesttime has top priority even at the early stages of a breeding program. The low-sucrose canes have practically disappeared. Only those with high sucrose concentrations are released to sugarcane growers for commercial trials.

The object of this paper is to evaluate the outstanding sugarcane varieties grown in Puerto Rico on the basis of their final sucrose concentrations at harvesttime.

MATERIALS AND METHODS

The data herein reported have been obtained from 41 Island-wide field experiments. Geographically these covered most of the areas where sugar-

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cane is grown in Puerto Rico: The north, east, west, and south coasts; the Guanajibo, Lajas, and Caguas inner lowlands; and the hilly areas near San Sebastián in the west-central region, and near Cayey in east-central Puerto Rico. A wide variety of soils was covered ranging from the lateritic Coto clay at Isabela through alluvials such as Coloso (Arecibo, Toa Baja, Añasco, Aguada, San Germán), Toa (Cayey, Hormigueros), San Antón (Guayanilla, Aguirre), Viví (Humacao), and Vega Baja (Río Piedras); and including reddish prairie such as Santa Isabel and Machete (Aguirre and Guánica); reddish chestnut and chernozem such as Fraternidad (Guánica) and Camaguey (San Sebastián), respectively; gray-brown podzolic such as Vía (Humacao); planosols like Sabana Seca (Arecibo), and a reclaimed solonchack such as Serrano near Ponce.

From 4 to 11 varieties were compared in each test, using a randomized block lay-out in the majority of the cases, split-plot designs in others where various fertility levels were also under trial, and lattice designs in a few. A total of 109 crops were harvested from the 41 experiments considered in this study, ranging from a plant cane in a few instances to a 6-crop cycle (1 plant cane and 5 ratoon crops) in others, with a mean number of 3 crops for all the experiments included.

In organizing the data a number of varieties included in the original investigation was discarded because they either did not appear in a sufficient number of experiments to make comparisons worth while, or because they are rapidly disappearing from cultivation in the Island, for instance P. (Palma), Tuc. (Tucumán), and some P.O.J. (Prooefstation Oost Java) canes. Others still were discarded because they attained no commercial importance after a number of years, such as a few of the P.R. (Puerto Rico) and M. (Mayagüez) canes. Some varieties such as the C.A.'s (Central Aguirre) and some of the B. (Barbados) were included, although they appeared in only a few recent experiments because, on general inspection, they seemed to be rather promising agronomically. The data were organized according to three broad climatic regions, namely, humid, including the north, east, and west coasts, and the interior; subhumid, including the northwest zone near Isabela; and semiarid, including the Lajas Valley and the rest of the southern coast south of the main divide.

PRESENTATION OF DATA AND DISCUSSION

Table 1 gives the weighted mean sucrose yields of the 20 selected varieties included in this study. Most of the cane varieties are grown over the whole Island in a wide range of climatic, edaphic, and managerial conditions, except the C.A. (Central Aguirre) canes which are as yet limited to the semiarid irrigated southern coast and inner valleys. The best sucrose producers for Puerto Rico as a whole were M.'s 336 and 28, P.R.'s 908, 907,

and 902, and C.A.'s 38-102 and 38-74. Of these, the P.R. 908 and the CA canes were not included in a sufficient number of trials to be considered in comparison with the other leading varieties. These varieties, as well as other promising ones from the next groups, need still more extensive testing before their performance can be correctly evaluated.

M. 336 outyielded all other varieties in the semiarid region with a mean sucrose content at harvesttime of 14.14 from 15 crops. Except for M. 28

TABLE 1.—*Weighted mean sucrose yields (as available 96° sugar percent cane) of 20 selected sugarcane varieties in each of 3 climatic areas and in Puerto Rico as a whole*

Variety	Crops (all areas)	Humid	Subhumid	Semiarid	Puerto Rico (all areas)
	Number				
P.R. 908	4	13.66	—	—	13.86
M. 336	42	13.63	—	14.14	13.81
P.R. 907	32	13.14	—	13.47	13.23
C.A. 38-102	4	—	—	13.16	13.16
P.R. 902	76	13.14	12.66	13.34	13.12
M. 28	25	13.68	12.19	—	13.02
C.A. 38-74	3	—	—	13.01	13.01
P.R. 905	54	12.82	12.36	12.71	12.74
C.A. 38-160	2	—	—	12.73	12.73
B. 34-104	23	12.39	12.63	13.47	12.70
B. 37-161	23	12.50	11.96	12.82	12.54
B.H. 10-12	42	12.19	—	12.60	12.35
M. 317	61	12.36	11.07	12.15	12.23
P.O.J. 2878	90	12.01	11.26	12.06	11.91
M. 275	73	11.91	10.72	11.80	11.83
P.R. 903	42	11.71	11.73	11.44	11.65
P.O.J. 2961	51	11.47	11.16	11.78	11.57
M. 341	5	11.33	—	10.89	11.07
F.C. 1017	4	—	11.05	—	11.05
P.R. 904	40	10.74	—	10.82	10.77
Weighted mean of all varieties...	699	12.35	11.80	12.44	12.32

and P.R. 908 it also produced more sucrose than any other variety in the humid region. The sucrose yield of M. 28 was 1.5-percent lower in the subhumid Isabela section than in the humid section.

The next best group of sucrose producers included P.R. 905, C.A. 38-160, B. 34-104 and 37-161, B.H. 10-12, and M. 317, with a mean range of 12.23 to 12.74 percent for the Island, irrespective of climatic influences. B. 34-104 seemed to produce better sucrose yields in southern Puerto Rico. P.R. 905 in 54 crops had a mean sucrose yield of 12.74 percent, and ranked among the best producers. In addition, because of the high tonnage of millable

cane that it produces, it yields large quantities of sugar to the acre and compares very favorably in this aspect with most of the other canes. The next lower sucrose producers were P.O.J. 2878 and 2961, M. 275 and 341, P.R. 903, and F.C. 1017. Yet all of them yielded over 11-percent available 96° sugar percent cane. P.R. 904, as evidenced by the mean yields of 40 crops, was an inferior sucrose producer as compared with other varieties, having a final sucrose concentration of less than 11 percent.

The variations in sucrose content for the same varieties in the different climatic areas shown in table 1 reveal that the varieties grown in the humid and semiarid areas are very similar having means of 12.35- and 12.44-percent sucrose, respectively. When the canes were grown in the subhumid region, however, their sucrose contents declined to a mean of 11.80.

When the varieties were grouped according to place of origin, the mean sucrose contents were highest for the Central Aguirre (C.A.) with 13.01 percent, next, in order, for Barbados (B.) 12.62, Mayagüez (M.) 12.48, and Puerto Rico (P.R.) 12.44, and last for Java (P.O.J.), with 11.78 percent. Plantings of the C.A. varieties were limited to the irrigated semiarid southern portion of the Island. The Barbados canes were used in all three climatic zones with good results. The P.R. varieties produced generally better yields of cane in the humid than in the semiarid area, although the sucrose content remained about the same for both.

A variety having a high sucrose content does not always give high yields in tons of cane. In fact, if the varieties listed in table 1 were ranked according to their yields of tons of millable cane per acre, many of the high-sucrose varieties would be low on the list. The Barbados canes B. 34-104 and 37-161, which appear tenth and eleventh in mean sucrose content for all areas (table 1), ranked as the leading varieties of tons of cane per acre in the recent variety field trials. Varieties M. 336 and M. 28, which rank high on the list for sucrose content, are relatively low in tonnage of cane per acre.

However, it is gratifying to see that the selection of new varieties has produced such changes that the leading sugar-producing varieties on the basis of hundredweights of 96° available sugar per acre are higher in both tonnage and sucrose content than the earlier varieties which they are steadily replacing. The trend is toward the production of sugarcane varieties that give high yields of cane and have a high sucrose content. The sugarcane breeders are striving to give the sugarcane grower the most compact and efficient producers of sugar per acre, which means more sugar at lower cost of production.

Table 2 shows the distribution of the sugarcane varieties considered in this study according to the last varietal census conducted by the Station (2)[2]. A single variety—P.O.J. 2878—occupies about two-thirds of the total

[2] Numbers in parentheses refer to Literature Cited, p. 34.

acreage in sugarcane. It is grown throughout the Island. Together with B.H. 10–12 it occupies over 80 percent of the total sugarcane acreage. Both varieties are inferior in sucrose production to a number of other proven varieties such as the M. 336, and P.R.'s 907 and 902. Furthermore, they are also inferior to those three and other canes in total sugar yields, both tonnage and sucrose content considered (1).

The superior sugarcane varieties M. 336 and P.R. 907, 908, and 902 resulted from crosses between the M. 28 and P.O.J. 2878. Botanically they

TABLE 2.—*Distribution of sugarcane varieties grown in Puerto Rico according to the 1949 varietal census*

Variety	Acreage	Percentage of total
	Acres	*Percent*
P.O.J. 2878	235,262	65.40
B.H. 10–12	54,681	15.20
M. 275	14,161	3.93
M. 28	11,964	3.33
P.R. 902	3,691	1.02
M. 336	2,196	.61
M. 317	1,257	.35
P.O.J. 2961	1,099	.30
P.R. 905	775	.22
B. 37-161	588	.16
P.R. 903	570	.16
M. 341	445	.12
P.R. 907	212	.06
B. 34-104	196	.05
F.C. 1017	63	.02
P.R. 904	20	.01
P.R. 908	18	.01
Others	32,547	9.05

resemble both of them in many characteristics. They are all vigorous canes erect or slightly decumbent, with good to excellent stooling and tillering capacity. They grow rather rapidly, are adapted to a wide range of climatic and edaphic conditions, and have no apparent defects in milling qualities. Reference can be made to Riollano (1) for a botanical description of the M. 336 and the P.R.'s 902, 905, and 907 canes.

Any consideration of the influence of variety on the sucrose content of cane would be incomplete without a discussion of the seasonal variation encountered in the sucrose content of a specific variety. In table 3 an example is given of such seasonal variation in sucrose observed during a variety trial. In any one crop year, varieties P.R. 902, M. 28, and P.R. 905 (with the exception of the second ratoon) outyielded P.O.J. 2878 in sucrose.

The mean difference in yield between the variety containing the most sucrose, M. 28, and that containing the least, P.O.J. 2878, was 1.05 percent. However, these varieties displayed a significant variation in sucrose content from one crop year to another. Table 3 shows that the plant-cane crop had the highest sucrose content, and the first and third ratoons the lowest. The mean variety variation in sucrose per crop year ran from a high of 13.54 for the plant cane to 11.34 for the first ratoon, a difference of 2.20. This seasonal difference was much higher than any difference en-

TABLE 3.—*Seasonal variation in mean sucrose percent cane for 4 varieties of sugarcane grown at Isabela Substation, 1946–51*[1]

Variety	Mean yield in sucrose percent cane for—				Mean of 4 crops
	Plant cane 1946–48	First ratoon 1948–49	Second ratoon 1949–50	Third ratoon 1950–51	
M. 28	13.63	11.68	12.87	12.02	12.55
P.O.J. 2878	13.01	10.67	11.81	10.52	11.50
P.R. 902	13.74	11.46	12.50	11.94	12.41
P.R. 905	13.78	11.55	12.27	12.18	12.45
Mean of all varieties...	13.54	11.34	12.36	11.67	12.23
Least significant difference needed between varieties of same crop at—					
5-percent level	0.35	0.47	0.52	0.41	0.28
1-percent level	.48	.65	.71	.57	.36
Least significant difference needed between crops at—					
5-percent level	0.44				
1-percent level	.66				

[1] Calculated from data of P. Landrau, Jr. and G. Samuels, The response of sugarcane to fertilizers: II. The Isabela Cycle (unpublished data).

countered between varieties. The cause of this seasonal variation will be discussed in a forthcoming article in this series.

It should be remembered that comparisons between the production of varieties from one crop season to another should be evaluated with due consideration for the seasonal-variation effect. Although a high-yielding sucrose variety will tend to maintain its level when compared with other varieties in the same crop season, it may show large variations in sucrose content from one season to another.

SUMMARY

Data were obtained from 41 field experiments located throughout the Island. From the whole group of varieties tested, 20 were selected for evaluation of their sucrose production at harvesttime. The data were

grouped according to three broad climatic areas, namely, humid, subhumid, and semiarid. Certain varieties were observed to produce better sucrose yields in a given climatic region, but in general, there were no significant differences among climatic regions for most varieties.

P.R.'s 908, 907, 902, and 905, M.'s 336 and 28, and C.A.'s 38-102 and 38-74 produced the highest sucrose yields at harvesttime. The superiority in this respect of M.'s 336 and 28, and P.R.'s 907, 902, and 905 has been definitely established. Other promising varieties need further testing. Most of these canes yield more total sugar than the standard commercial P.O.J. 2878 and B.H. 10–12 canes, which cover more than 80 percent of the total land area where sugarcane is grown in Puerto Rico.

The important bearing of seasonal variation on sucrose content of varieties is discussed. Seasonal differences in the performance of individual varieties have proved to be much greater than differences encountered between varieties in the same season.

RESUMEN

Se obtuvieron datos de 41 experimentos de campo dispersos por toda la Isla. Del grupo de variedades probadas, se seleccionaron 20 para la evaluación de su producción relativa de sacarosa al tiempo de la recolección. Los datos se agruparon de acuerdo con tres zonas climáticas amplias, a saber: Húmeda, subhúmeda y semiárida. Se observó que algunas variedades produjeron mejores rendimientos en una zona que en otra, pero en términos generales no se registraron diferencias significativas en la producción media de sacarosa de la mayoría de las variedades debido a la zona. Las variedades P.R. 908, 907, 902 y 905; M. 336 y 28; y C.A. 38-102 y 38-74 produjeron los más altos rendimientos de sacarosa. La superioridad en este respecto de las variedades M. 336 y 28 y P.R. 907, 902 y 905 ya ha sido definitivamente corroborada. Otras variedades prometedoras requieren aún más experimentación antes de poder evaluarlas definitivamente. La mayoría de estas variedades producen mayores rendimientos totales de azúcar que las variedades comerciales más extensamente cultivadas en la Isla, como las P.O.J. 2878 y B.H. 10–12, las cuales ocupan más del 80 porciento del área total dedicada al cultivo de la caña de azúcar. Se señala la importancia de las variaciones del clima en el contenido de sacarosa de las variedades.

LITERATURE CITED

1. Riollano, A., Nuevas variedades de caña de azúcar; Univ. of P. R., Agr. Expt. Sta., Bul. **91** 1951. (A compilation of data from 28 experiments.)
2. Silva, E. and Serra, G., Census of sugarcane varieties grown in Puerto Rico for the 1949 crop; Univ. of P. R., Agr. Expt. Sta., mimeographed report, Feb. 1950.

TILLAGE TESTS: II, THE BENEFICIAL EFFECT OF SUBSOIL FERTILIZATION ON SUGARCANE YIELDS

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INTRODUCTION

The influence of deep tillage in loosening tight subsoil layers is generally considered desirable because physical conditions suitable for root development, such as rapid riddance of excess water and adequate aeration, are thus promoted. The available literature concerning this subject embodies rather wide discrepancies concerning the effect of deep tillage upon crop yields, but it is generally accepted that with improved drainage and aeration, crop plants develop more extensive and deeper root systems. Consequently, plant roots can exploit a larger volume of soil in their search for moisture and nutrients. Soils with fertile or moderately fertile subsoil layers may release mineral nutrients helpful for crop development. However, subsoils are generally infertile and plant nutrients must be supplied at lower depths if a favorable fertility level is to be maintained for plant growth.

Subsoiling has been a regular practice in some Puerto Rican cane fields, particularly in the southern irrigated plantations; but there is no experimental evidence to indicate its beneficial effect on soil tilth or crop yields. Subsoil fertilization and liming are virtually unused by our sugarcane growers. A regular practice on our plantations is to apply the fertilizer to the soil next to the base of the sugarcane seedling in plant cane, and to the clump in ratoon cane.

This paper reports the effects of subsoiling and subsoil fertilization on sugarcane yields. The results may help to clarify some of the concepts involved and to correct the apparent discrepancies found in the literature.

REVIEW OF LITERATURE

Smith, et al. found that subsurface tillage produced more beneficial effects on soil condition when the subsoil was shattered while semidry (22)[2], so that the large soil masses were effectively broken up and more favorable physical characteristics were obtained. The breaking of plowpans and loosening of tight subsoil layers have proven beneficial to crops in some of the older agricultural areas (2, 5, 8, 12, 15, 18, 19, 20). However,

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[2] Numbers in parentheses refer to Literature Cited, pp. 42–3.

in some cases no effects on yield were reported from deep tillage in various areas of the Great Plains and Middle West in continental United States (11, 13, 23; 3, 21). Martínez and Lugo-López observed highly significant differences in the minimum infiltration capacity of heavy soils where subsoils were broken, as compared with check plots tilled as is customary on the plow layer only (10).

Wolters observed the beneficial effects of hook subsoiling in Hawaii on older ratoon crops (25) and Borden held that heavy stooling and shoot growth occurred primarily because the fertilizer got well down into the lower layers of the soil (1). In the same article, Borden reported data from Mitscherlich's pot tests using Sudan grass and comparing differences in yields between surface soils and subsoils at various fertility levels. He concluded that good aeration by itself was insufficient to make subsoils produce satisfactory yields. But, when the fertility level of the subsoil was raised to that of the surface soil, the yields obtained from each were not significantly different. Woodruff and Smith obtained very significant results in their experiments with sweetclover in one Missouri soil when subsoil liming accompanied the tillage operation; a more extensive and deeper root system was developed (26).

In view of the above it is important to emphasize the fact that, since there are soils where roots fail to develop well below the surface layer because of restricted aeration, and since there are also soils where roots fail to develop even under favorable aeration and internal drainage, the lack of available nutrients in the subsoil is probably a limiting factor for root extension and crop growth and production. In a previous paper a more detailed discussion of the theoretical considerations involved was presented (9).

EXPERIMENTAL PROCEDURE

About 10 acres of land were selected at Colonia Preston, a large sugar estate owned by the Eastern Sugar Associates in east-central Puerto Rico. Various pits were dug at different parts of the field to study the morphological characteristics of the soil. In addition, soil cores for laboratory analyses were taken with a Kelley (Utah) soil-sampling machine (6).

The pH was determined electrometrically by using a Macbeth pH meter with a glass electrode. Total nitrogen was determined by the standard Kjeldahl method and the organic matter by the simple colorimetric Schollenberger technique. Total exchange capacity and exchangeable bases were determined as suggested by Peech (14).

The soil, previously mapped as Vía silty clay, appeared upon field examination more nearly to approach a Caguas silt loam (17). The plow layer was a light grayish-brown silt loam with a weak fine granular structure and contained many small dark concretions with a mean diameter of

one-eighth of an inch. It was underlain by a 9-inch, highly mottled transition layer with a well-developed fragmental blocky structure. Beyond the 16-inch depth the soil was highly mottled with gray shades predominating, and was mostly a tight plastic clay which looked like putty and had a fragmental-blocky structure, coarser than the layer above.

A triple-lattice design was used for the experimental lay-out (4). The plots were rather large, 200 feet long by 20 feet wide, to provide ample space for the heavy machinery used. Land preparation began on October 11, 1950, when the sod was disked twice, and was followed by plowing and harrowing three times to a depth of about 12 inches. Furrows were made 5 feet apart, to accommodate four rows of cane in each plot. The field

TABLE 1.—*Treatment differentials established on the experimental field on a heavy claypan soil in east-central Puerto Rico, showing other treatments occurring in the same group according to design used*

Treatment No.	Description	Other treatments in the same group[1]
1	Check	2, 3, 4, 5, 7, 9
2	Subsoiling	1, 3, 5, 6, 7, 8
3	Subsoiling + fertilizer on subsoil	1, 2, 4, 6, 8, 9
4	Subsoiling + lime on subsoil	1, 3, 5, 6, 7, 8
5	Subsoiling + fertilizer and lime on subsoil	1, 2, 4, 6, 8, 9
6	Subsoiling and mole drainage	2, 3, 4, 5, 7, 9
7	Subsoiling and mole drainage + fertilizer on subsoil	1, 2, 4, 6, 8, 9
8	Subsoiling and mole drainage + lime on subsoil	2, 3, 4, 5, 7, 9
9	Subsoiling and mole drainage + lime and fertilizer on subsoil	1, 3, 5, 6, 7, 8

[1] Refer to table 3 for the grouping system.

was then ready for establishing the treatment differentials and planting, but these operations were deferred to a later date because of the unusually heavy rains during the latter part of November and early December. About the middle of January, after a few days of sunlight and no rain, a fourth disking was made to eliminate weed growth, and the furrows were opened again. Surface drainage was provided by open ditches placed at right angles to the furrows every 25 feet. These cross ditches led to larger ones which carried the water out of the field.

The treatment differentials were established during the period from January 17 to 24, 1951, as described in table 1. In this table also are shown the other treatments which occurred in same group with each respective treatment.

For these treatments an International TD-9 diesel crawler tractor,

wide-thread model (60-inch width center to center of tracks), with 16-inch track shoes; a heavy-duty equalizer spring; and extended tracks and track frames, was used. A hydraulic system consisting of pump, valve, tank, and hoses, to operate an International-Universal tool-bar (basic) was directly connected to the tractor. The tool-bar floated and was hinged for horizontal movement. On this bar was mounted a heavy-duty standard with a subsoil point and a removable mole attached. A fertilizer attachment for subsoil was mounted so as to be motivated by the tractor's power take-off which stopped automatically when the tool-bar was in the raised position for turning and transporting the tractor, and started automatically when the tool-bar was lowered. The standard was so graduated that the subsoil point would penetrate 30 inches.

In treatments 3, 5, 7, and 9, a 13-3-12 fertilizer was applied to the subsoil at the rate of 1,000 pounds to the acre. In treatments 4, 5, 8, and 9, an application of limestone at the rate of 1,000 pounds to the acre was made at the subsoil break-point, as lime-requirement tests indicated (16). Each treatment was replicated nine times. Cane variety P.O.J. 2878, standard for the region, was planted in the period from February 7 to 21. Each plot had four rows of cane 5 feet apart. Two applications of fertilizer 13-3-12 were made later to a total of 2,000 pounds to the acre. The first and second surface applications of fertilizer were at only half the rate for plots fertilized at the subsoil as for those that had not previously received this subsoil treatment. Other agronomic practices were conducted as was customary for the region.

The plant crop was harvested during the period from April 21 to 26, 1952. The cane of each plot was weighed in the field and samples of 20 canes each were taken at random from each plot. They were milled at the Station and the juice samples analyzed for Brix and polarization. The yield of available 96° sugar percent cane was calculated from that data and the weight of the sample and the juice obtained.

RESULTS AND DISCUSSION

The results of the statistical study of the data on sugar yields of the plant crop are presented in tables 2 and 3. Table 2 shows the analysis of the total sum of squared deviations of the data. The values for B and E are 144.20 and 49.24, respectively. These values are further used in correcting the mean yields obtained. Table 3 gives the corrected mean sugar yields for each tillage treatment. The form of presentation facilitates comparison between treatments to detect their significance.

The mean sugar yield of the check plots was 91.5 hundredweights to the acre. The mean sugar yield of all plots, including checks, (treatments 1, 2, 4, 6, and 8) which received all the fertilizer on top of the soil, as is customary

in sugarcane fields, was only 92.4, whether sufficient lime was added to satisfy the lime requirement of the subsoil or not. A mean sugar yield of 106.8 hundredweights to the acre was obtained from all plots (treatments 3, 5, 7, and 9) where half of the fertilizer was applied at the subsoil break-

TABLE 2.—*Analysis of total sum of squared deviations of sugar yield data obtained from tillage experimental field in east-central Puerto Rico*

Source of variation	Degrees of freedom	Sum of squares	Mean square
Replications	8	5,711.29	
Component *a*	12	1,730.44	144.20 = *B*
Component *b*	6	111.43	
Blocks (eliminating treatments)	18	1,841.87	
Treatments (eliminating blocks)	8	4,283.30	
Error (intrablocks)	46	2,265.06	49.24 = *E*
	80	14,101.52	

TABLE 3.—*Corrected mean sugar yields for each treatment in tillage experimental field in east-central Puerto Rico*[1]

Treatment	1 (*a*)	2 (*b*)	3 (*c*)
Cwts. of sugar per acre	91.5	91.0	104.7
Treatment	4 (*c*)	5 (*a*)	6 (*b*)
Cwts. of sugar per acre	95.4	104.9	91.5
Treatment	7 (*b*)	8 (*c*)	9 (*a*)
Cwts. of sugar per acre	108.3	94.4	109.1

[1] Lower-case letters in parenthesis refer to *Z* grouping in the statistical analyses. For other treatments within the same group see table 1.

L.S.D. for treatments within the same group:
at the 5-percent level 7.26
at the 1-percent level 9.70
L.S.D. for treatments not within the same group:
at the 5-percent level 7.77
at the 1-percent level 10.76

point and half on the surface soil, whether lime was applied at the subsoil or not. The mean sugar yield of all plots receiving fertilizer in the subsoil was significantly higher than that from the plots where all the fertilizer was applied to the topsoil.

As previously pointed out, the common practice in sugarcane fields is to place the fertilizer on top of the soil surface. This practice probably encourages the development of rather shallow root systems. Yields depend

upon the volume of soil, as well as upon that portion of its nutrient content that crop plants can exploit. It is a common belief that the sugarcane plants are shallow-rooted. Lee, in his studies on the root distribution of sugarcane in Hawaii observed that more than 90 percent of the roots were found in the topmost 16 inches of soil (7).

Veihmeyer and Hendrickson have shown that one of the controlling factors in root penetration is soil density (24). There is a distinct possibility that a deeper root system can be developed by cane plants in compact soils if both the physical and chemical properties of the subsoils are im-

TABLE 4.—*Mean pH, organic matter, nitrogen, total exchange capacity, and exchangeable bases of soil where tillage experiment is located*

Factor	Values at soil depths of—			
	0–7″	7–16″	16–26″	26″
pH	6.6	6.0	4.9	5.0
Organic matter (percent)	1.0	(1)	(1)	(1)
Nitrogen (percent)	.15	.02	.02	(1)
Total exchange capacity (m.e./100 gm. dry soil)	9.5	10.0	11.4	12.5
Total bases (m.e./100 gm. dry soil)	8.3	7.8	5.4	4.3
Calcium (m.e./100 gm. dry soil)	7.6	7.3	4.5	2.5
Magnesium (m.e./100 gm. dry soil)	.6	.5	.8	1.6
Manganese (m.e./100 gm. dry soil)	.005	.01	.05	.06
Potassium	(1)	(1)	(1)	(1)

[1] Trace.

proved. Furthermore, in soils with subsoils in favorable physical condition, the addition of plant nutrients will also promote better root development. If the conditions that influence root extension are favorable both from the standpoint of tilth and nutrient availability, better crop yields are likely to be obtained.

Table 4 shows the fertility status of the soil where the experiment was carried out. This soil was slightly acid at the surface and acid in the subsoil, and rather low in fertility. It was not well supplied with organic matter, nitrogen, potassium, and calcium. Except for the exchangeable calcium, which decreased from 7.6 m.e. in the surface soil to 2.5 m.e. in the lower layer, there were no important differences in the fertility status of surface soil and subsoil. The total exchange capacity was moderate through-

out the profile. It is of importance to fertilize this soil adequately if profitable crop yields are to be obtained.

In the area where this experiment was carried on, as well as in Puerto Rico as a whole, sugarcane is generally fertilized quite heavily. The mean yields of sugar obtained from the plant crop herein reported emphasize the necessity for adequately fertilizing both soils and subsoils. A mean significant difference of more than 14 hundredweights of sugar was obtained when the fertilizer application was split equally between soil and subsoil. This is an increase of 16 percent on a basis of the yields of the plots where all the fertilizer was applied on the surface. There were no significant differences between the mean sucrose contents of the cane harvested from plots where the fertilizer was placed at the top and those where it was split equally between soil and subsoil.

The differences in sugar yields were attributable to increased cane tonnage produced by subsoil fertilization. At current prices in the world market 14 hundredweights of sugar have a value of approximately $85. Since nearly two-thirds of this value goes to the grower, after deducting milling expenses, a gross income of $56 can be obtained. Even when due allowance is made for the increased power and labor that subsoil fertilization demands, and the increased harvesting and hauling costs involved for the extra tonnage, the sugarcane grower will obtain a larger net profit when fertilizing the subsoil and the topsoil both than when fertilizing only the latter.

The residual effect of the original subsoil fertilization remains to be determined in succeeding ratoon crops. It might prove advantageous to fertilize the subsoil yearly. Additional information is needed from other soil areas. Meanwhile the result available provide a rather important reference point as to what to expect from subsoiling and subsoil fertilization in sugarcane-producing areas.

SUMMARY

Data are presented here on sugar yields obtained from a heavy claypan soil under different tillage treatments. The mean sugar yield of all plots, including checks, which were fertilized only on the topsoil, was 92.4 hundredweights to the acre, whether sufficient lime was added to satisfy the lime requirement of the subsoil or not. The mean sugar yield of all plots which received half of the fertilizer in the subsoil and half in the surface soil was 106.8 hundredweights to the acre, whether lime was present or absent in the subsoil. The mean differences were significant. It seems that when the conditions that influence root extension are favorable both from the standpoint of tilth and nutrient availability, better crop yields are likely to be obtained, and fertilization of the subsoil fosters such condition.

RESUMEN

Se presentan aquí datos sobre la producción de azúcar en un suelo pesado con un "claypan" sometido a varios tratamientos durante las operaciones de preparación del terreno y cultivo. La producción media de azúcar en las parcelas, incluyendo los testigos, donde todo el abono se aplicó en la superficie del suelo, como se acostumbra corrientemente en el cultivo de caña, fué de 92.4 quintales por acre; lo mismo en presencia que en ausencia de cal en el subsuelo. La producción media de las parcelas, donde la mitad del abono se aplicó en el subsuelo y la otra mitad en la superficie, fué de 106.8 quintales por acre, tanto en ausencia como en presencia de cal. Las diferencias medias son significativas. Es de esperarse, que cuando las condiciones que afectan el desarrollo de las raíces sean favorables, tanto desde el punto de vista de las propiedades físicas, como de las propiedades químicas del suelo, se obtengan mejores rendimientos.

LITERATURE CITED

1. Borden, R. J., Are there possibilities on subsoil fertilization?, Gilmore Hawaii Sugar Manual, pp. 19–25, 1947–48.
2. Brasher, E. P., Effect of plowing and discing soils on the yield of tomatoes, muskmelons and potatoes, *Amer. Soc. Hort. Sci. Proc.* (1948) **51** 357–8 1949.
3. Chilcott, E. C. and Cole, J. S., Subsoiling, deep tilling and dynamiting in the Great Plains, *J. Agr. Res.* **14** 481–521 1918.
4. Cox, G. M., Eckhardt, R. C. and Cochran, W. G., The analysis of lattice and triple lattice experiments in corn varietal tests, Res. Bul. **281,** 66 pp., Iowa State Coll. of Agr., Agr. Expt. Sta., September 1940.
5. Jones, G. D., Method and effect of deep tillage, *Agr. Eng.* **20** 61–3 1939.
6. Kelley, O. J., Hardman, J. A. and Jennings, D. J., A soil sampling machine for obtaining two-, three-, and four-inch diameter cores of undisturbed soil to a depth of six feet, *Soil Sci. Soc. Amer. Proc.* **12** 85–7 1948.
7. Lee, H. A., The distribution of the roots of the sugarcane in the soil of the Hawaii Islands, *Plant Physiol.* **1** 363 1926.
8. Lill, J. G., Plowing depths and fertilizers affect sugar beet crop, *Mich. Agr. Expt. Sta. Quart. Bul.* **13** 122–127 1931.
9. Martínez, M. B. and Lugo-López, M. A., Plans for research on the effect of subsoiling and subsoil fertilization on sugar cane fields, *Sugar J.* **14** 36–43 1951.
10. Martínez, M. B. and Lugo-López, M. A., Tillage tests: I, Effect of subsoiling and mole drainage upon the minimum infiltration capacity of a heavy claypan soil of the Tropics, *J. Agr. Univ. P. R.* **36**(2) 179–85 1952.
11. Mosier, J. G. and Gustafson, A. F., Soil moisture and tillage for corn, Ill. Agr. Expt. Sta. Bul. **181** 563–86 1915.
12. Nissley, C. H., Our forgotten soil, *Country Gent.* **110**(2) 15 1940.
13. Osborn, W. M., Rotation and tillage experiments at the Lawton (Okla.) Field Station, 1917–1930, U. S. Dept. Agr. Tech. Bul. **330** 1932.
14. Peech, M., Determination of exchangeable bases in soils, *Ind. Eng. Chem.* **13** 436 1941.
15. Randolph, J. W., Reed, I. F. and Gordon, E. D., Cotton-tillage studies on Red Bay sandy loam, U. S. Dept. Agr. Cir. **540** 1940.

16. Riera, A., Laboratory recommendations of lime to an acid soil checks with expected pH changes, *J. Agr. Univ. P. R.* **30**(3) 184–185 1946.
17. Roberts, R. C., Soil Survey of Puerto Rico, U.S.D.A. Series 1936 (9) Bur. of Plant Industry in cooperation with Univ. of P. R. Agr. Expt. Sta. 503 pp., 1942.
18. Russell, E. W. and Keen, B. A., Studies in soil cultivation: VII, *J. Agr. Sci.* **28** 212–33 1938.
19. Russell, E. W. and Mehta, N. P., Studies in soil cultivation: VIII, *J. Agr. Sci.* **28** 272–98 1938.
20. Russell, E. W. and Keen, B. A., Studies in soil cultivation: X, *J. Agr. Sci.* **31** 326–47 1941.
21. Sarvis, J. T. and Thysell, J. C., Crop rotation and tillage experiments at Northern Great Plains Field Station, Mandan, N. Dak., U. S. Dept. Agr. Tech. Bul. **536** 1936.
22. Smith, D. D., Woodruff, C. M. and Whitt, D. M., Building a soil deeper, *Agric. Eng.* **28** 347–8 1947.
23. Smith, R. S., Experiments with subsoiling, deep tilling and subsoil dynamiting, Ill. Agr. Expt. Sta. Bul. **258** 1925.
24. Veihmeyer, F. J. and Hendrickson, A. H., Soil density and root penetration, *Soil Sci.* **65** 478–93 1948.
25. Wolters, W., Root distribution, *Reports Assn. Hawaiian Sugar Tech.* pp. 71–80, 1928.
26. Woodruff, C. M. and Smith, D. D., Subsoil shattering and subsoil liming for crop production on claypan soils, *Soil Sc. Soc. Amer. Proc.* **11** 539–42 1946.

FAILURE OF PREHARVEST FOLIAGE SPRAYS WITH 2,4-D AND MALEIC HYDRAZIDE TO AFFECT THE SUCROSE CONTENT OF SUGARCANE

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INTRODUCTION

Many substances have been synthesized recently which can induce profound alterations in the morphology and physiology of plants. Most of these are known as hormones or plant-growth regulators. The possibility of increasing the sucrose concentration of certain plants through the use of these substances has been given some consideration (10)[2].

In sugarcane, as well as in sugar beet production, one of the main goals of the farmer is to harvest a heavy tonnage to the acre with the highest possible sucrose concentration. Considerable progress has been made in obtaining reasonably large sugarcane crops through the use of better varieties, improved fertilizer practices, and adequate cultivation techniques. However, variations in sucrose concentration still elude practical control. This paper reports preliminary work conducted in Puerto Rico to test the effects of preharvest sprays of sugarcane with 2,4-D and maleic hydrazide on the final sucrose content of cane.

REVIEW OF LITERATURE

For the past two decades many plant-growth regulators or hormonelike substances have appeared on the market for agricultural use, mainly as weed killers. Among them 2,4-D has been most widely used. Attempts have recently been made to apply 2,4-D just prior to harvest as a regulator to induce the conversion of starches in the green-leaf section of the stalk and in the leaves into sucrose, with a consequent increase in the final sucrose accumulation of the millable cane.

Beauchamp (1) reported that, in Cuban plantations, increases in sucrose of 1.4 or 2.0 percent were obtained from dusting the cane foliage of P.O.J. 2878 and Media Luna $^{3}/_{18}$ with 4 to 6 ounces to the acre of the sodium salt of 2,4-D. The effects were more marked during the first 10 days fol-

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[2] Numerals in parentheses refer to Literature Cited, p. 51.

lowing treatment. Promising results have been reported from other areas also (3).

However, Loustalot, et al. (4), at Mayagüez, obtained no increases in the sucrose content of M. 336 by spraying the foliage with 0.2-percent isopropyl ester of 2,4-D. Lugo-López and Grant failed to induce any significant differences in the sucrose content of P.O.J. 2878 by spraying with the sodium salt of 2,4-D at concentrations of 10, 20, and 30 pounds to the acre, at three intervals prior to harvest (5). In the last two cases mentioned the control plots produced about the same sucrose yields at harvesttime as the treated plots.

There have been also reports that indicate the 2,4-D applications may affect the sugar metabolism of other plants. Wort (14) from British Columbia reported increases in the total sugar content of buckwheat after treatment with small doses of the ammonium salt of 2,4-D within 1 day after the application.

Maleic hydrazide, one of the latest hormonelike substances to be described, has been found to have striking effects on plant growth, development, and flowering (8). Naylor and Davis (7) observed that corn plants sprayed with maleic hydrazide exuded droplets of sucrose and accumulated anthocyanin pigments. Quantitative sugar analysis indicated a thirteenfold increase in sugar concentration. Ririe and Mikkelson (11) obtained evidence that maleic hydrazide influences sugar beet growth and increased the sucrose content. Foliar sprays containing 0.3 and 0.025 percent made at the rate of 50 gallons per acre were applied, and the sucrose content was determined at three dates of harvest. An exudate appearing on barley after applications of maleic hydrazide was analyzed for sucrose by Currier et al. (2). Sucrose and starch were increased in cotton following application of maleic hydrazide (6). However, Stout (12) and Peto, et al. (9) reported no significant increases in the sucrose content of sugar beets when treated with maleic hydrazide. Wittwer and Hansen (13) reported that sprays with 0.25-percent maleic hydrazide 30 to 40 days prior to harvest, or even as late as 3 or 5 days before harvest, considerably decreased the storage losses of sucrose in sugar beets.

EXPERIMENTAL PROCEDURE

Two fields were selected, one at the Station Farm at Río Piedras in the north and one at Colonia Río Grande of the Eastern Sugar Associates, near Central Santa Juana between Caguas and Gurabo, in east-central Puerto Rico. Both fields had been planted to P.O.J. 2878 and several ratoon crops harvested following the original plant cane. At Río Piedras the soil had been classified as a Vega Baja clay, a rather extensive, level, alluvial sugarcane soil of the north-coastal region. At Río Grande the soil was a

Mabí clay occurring on long gentle slopes or nearly level areas throughout the humid sections, in association with the Juncos and Múcara soils derived from tuffaceous materials.

Both fields were divided into 6 blocks with 6 and 10 plots each at Río Piedras and Río Grande, respectively. The area of the plots was approximately 0.01 acre and they were nearly square. A row of cane was cut around each plot and two rows were left standing between each two plots to serve as buffer strips. There was approximately 20 feet between each two plots. The row of cane eliminated around each plot provided a very convenient pathway to facilitate spraying and sampling operations. The experimental design followed a randomized block layout with 6 and 10 treatments at Río Piedras and Río Grande, respectively, with 6 replications in each case. The treatments were as follows:

Río Piedras experiment: 0, 2.5, 5.0, 7.5, 10.0, and 12.5 pounds to the acre of 2,4-D, acid basis.

Río Grande experiment: Control; 0.025, 0.05, 0.10, and 0.20 percent of 2,4-D, acid basis; and 0.025, 0.05, 0.10, 0.50, and 2.00 percent of maleic hydrazide.

The 2,4-D was provided as the 97-percent sodium salt monohydrate, equivalent to 82-percent 2,4-dichlorophenoxyacetic acid. Maleic hydrazide (1,2-dihydropyridazine-3,6-dione) formulated as a water-soluble diethanolamine salt, containing 30 percent of the active ingredient by weight as used. All dosages are expressed on the active-ingredient basis. Dreft at the rate of 0.05 percent was added to the sprays as a wetting agent and applications were made until run-off occurred on the cane leaves.

A common knapsack sprayer was used and the required amount of the salt was dissolved in 1 gallon of water which was enough to spray thoroughly the cane leaves in each plot. An extension was attached to the hose and the nozzle was tied to a bamboo pole 12 or 14 feet in length which could be raised well above the cane and allow the spray to fall on the cane foliage. The spraying operations were started at about 6:00 a.m. to avoid violent drafts and thus minimize the error in spraying. Samples of 10 canes each were obtained from each plot at random and taken to the Station mill at Río Piedras. After grinding, the juice was sampled and analyzed for Brix and polarization. The purity and available 96° sugar percent cane were calculated from these data.

At Río Piedras samples were taken every day for 15 days following the treatments on April 14, 1951, and later every 5 to 7 days until all the cane was harvested at the end of 46 days. At Río Grande, samples were taken for 4 consecutive days after establishing the treatment differentials on February 26, 1952, and thereafter at intervals of 3 to 11 days, the sampling inter-

vals being more extended towards the end of the experiment. The last sampling was made on May 9, 1952, some 72 days after the treatments were given.

RESULTS AND DISCUSSION

The Río Piedras experiment was designed primarily to continue the previous two experiments performed at Río Piedras and Humacao, reported

TABLE 1.—*Daily fluctuations in available 96° sugar yields of POJ 2878 cane sprayed with 2,4-D prior to harvesting (Río Piedras)*

Day of harvesting after treatment	Available 96° sugar when indicated pounds of 2,4-D per acre were used						Means
	0	2.5	5.0	7.5	10.0	12.5	
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	14.2	14.9	14.2	13.6	14.9	13.9	14.3
2	14.2	14.2	14.8	13.9	14.2	14.2	14.3
3	14.2	13.8	14.3	14.2	14.3	13.5	14.1
4	13.7	13.8	14.0	13.9	13.9	14.1	13.9
5	14.1	14.1	14.1	14.3	14.3	13.4	14.1
6	14.2	14.3	13.8	14.1	14.3	14.3	14.2
7	14.2	14.7	14.6	13.7	14.1	14.3	14.3
8	13.9	14.1	13.7	14.0	13.7	14.0	13.9
9	14.2	13.9	13.9	14.4	14.1	14.3	14.1
10	13.7	13.9	14.4	14.3	14.0	13.5	14.0
11	14.9	13.9	13.9	14.7	14.3	14.5	14.4
12	14.4	14.7	14.5	14.0	14.4	14.7	14.4
13	14.4	14.1	13.8	13.4	14.4	14.0	14.0
14	14.4	—	13.7	—	13.9	14.3	14.0
15	14.3	14.8	14.4	13.3	13.8	14.4	14.2
20	14.7	13.9	13.4	14.1	13.5	13.4	13.8
25	14.4	—	—	—	13.5	12.9	13.6
31	13.5	12.6	—	—	12.2	13.2	12.9
38	13.3	—	—	—	12.1	12.4	12.6
42	12.8	—	—	—	12.9	13.2	12.9
46	12.8	—	—	—	11.5	12.1	12.1
Means of treatments	14.0	14.1	14.0	14.0	13.7	13.7	13.9

elsewhere (5). It was felt that the failure to affect the metabolism of the sugarcane plant favorably might be attributed, in part, to the extremely large doses of 2,4-D used in those experiments. In the next experiment at Río Piedras smaller quantities of 2,4-D were applied. The daily variations in Brix, polarization, purity, and available 96° sugar percent cane were observed for 15 consecutive days, and thereafter every 5 to 7 days for more than 1½ months. Table 1 gives a summary of the sucrose yields obtained

TABLE 2.—*The sucrose percent cane yields of P.O.J. 2878 at various cutting intervals, as influenced by applications of 2, 4-D and maleic hydrazide (Colonia Rio Grande)*

Treatment No.	Treatment[1]	Sucrose percent cane yields at dates of cutting indicated												Mean
		Feb. 27	Feb. 28	Feb. 29	Mar. 1	Mar. 4	Mar. 12	Mar. 18	Mar. 27	Apr. 7	Apr. 17	Apr. 28	May 9	
1	Control	10.23	10.30	10.34	10.61	9.85	10.82	10.47	10.05	11.76	10.33	11.98	11.71	10.70
2	0.025 percent MH 30	11.20	10.38	10.19	9.99	10.19	10.58	10.80	10.34	11.52	11.70	11.86	12.20	10.91
3	.05 percent MH 30	10.76	10.39	10.55	10.24	9.79	9.99	11.03	9.97	11.51	11.25	10.84	11.87	10.68
4	.10 percent MH 30	10.33	10.50	10.44	10.70	10.55	10.55	11.31	10.29	11.15	11.55	11.56	12.05	10.92
5	.50 percent MH 30	10.61	10.46	10.65	10.46	10.60	10.43	9.79	10.32	11.08	11.38	11.66	11.66	10.76
6	2.00 percent MH 30	10.56	10.59	11.13	10.42	10.52	10.74	10.51	10.19	10.97	11.61	12.15	11.73	10.92
7	.025 percent 2,4-D	10.64	10.53	10.39	10.41	10.17	10.32	10.87	10.44	11.59	11.63	11.45	11.45	10.82
8	.05 percent 2,4-D	10.73	9.75	10.36	9.88	10.09	10.96	10.70	10.34	11.83	11.73	11.91	11.08	10.78
9	.10 percent 2,4-D	10.78	10.64	10.61	10.20	10.23	10.88	10.39	10.28	11.58	12.04	11.90	11.62	10.93
10	.20 percent 2,4-D	11.10	10.73	10.37	10.81	10.43	10.81	10.85	10.48	11.90	12.09	12.31	12.16	11.17
Mean of all treatments		10.70	10.43	10.50	10.39	10.24	10.60	10.67	10.27	11.49	11.53	11.76	11.75	10.86
Least significant difference needed for comparison at the:														
5-percent level		0.87	0.94	0.95	0.95	0.97	0.82	0.92	1.13	0.88	1.15	1.25	0.49	
1-percent level		1.17	1.25	1.27	1.26	1.30	1.09	1.23	1.51	1.18	1.53	1.67	.66	

[1] MH = Maleic hydrazide.

for the period. No significant differences were observed between the means of the various treatments.

The Río Grande experiment was designed to test still smaller doses of 2,4-D and included maleic hydrazide treatments. Table 2 shows the yields of available 96° sugar percent cane at various intervals for P.O.J. 2878

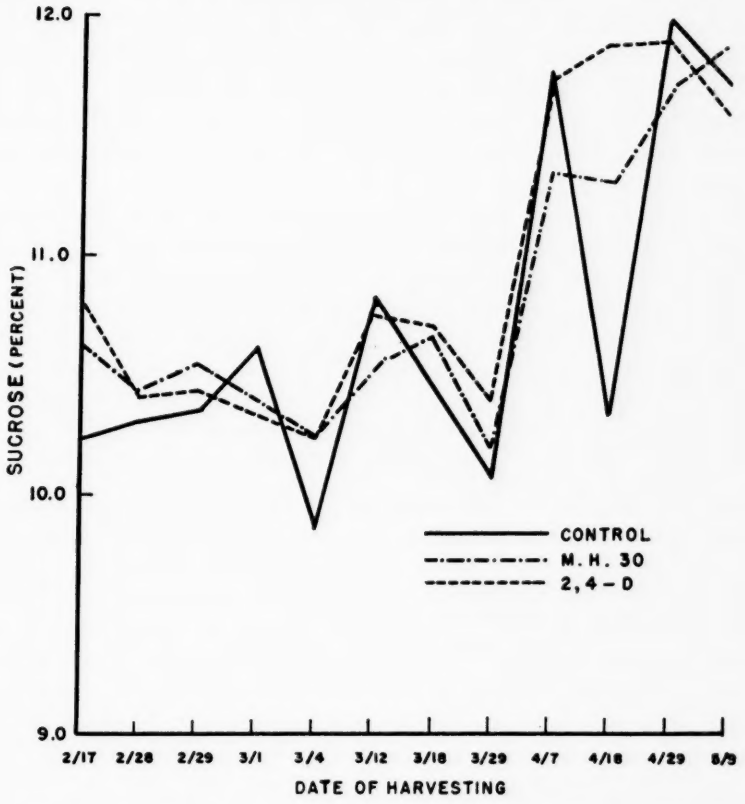

FIG. 1.—Mean results of the combined 2,4-D and the combined maleic hydrazide treatments, and of the controls, showing percentage of sucrose at various harvesting dates.

treated with 2,4-D and maleic hydrazide. There were no significant differences between the means of the treatments. The yields from the plots receiving a 0.20-percent solution of 2,4-D were quite consistently higher throughout the harvesting season than those from the check plots, but the differences were not significant even at the 5-percent level. The mean results of the combined 2,4-D and the combined maleic hydrazide treatments, as well as of the controls, are shown graphically in figure 1.

There were some definite high and low sucrose levels during the harvesting season, and particularly towards the end of it, the canes from the treated plots seemed able to retain their sucrose accumulation while the sucrose yields of the check plots reached a very low level.

A general inspection of the data indicates that the daily variations in sucrose content throughout the harvesting season were attributable rather to weather conditions than to treatments. There is no doubt that weather variations have a pronounced effect on the final sucrose accumulation of cane at harvesttime. Furthermore, there are also indications that each cane variety has an optimum period during which its sucrose accumulation reaches a peak. Both of these factors will be considered in detail in forthcoming reports.

The use of plant-growth regulators in an effort to affect the ripening of the green-leaf millable stalks of cane at harvesttime should not be attempted yet by sugarcane growers in light of the results obtained in these experiments. The evidence from experimental data in Puerto Rico is rather discouraging. However, the physiologic basis for expecting favorable metabolic changes from preharvest sprays with growth regulators is sound, but further work must be undertaken before advancing any definite conclusions.

SUMMARY

Data are presented here on the effect of applications of 2,4-D and maleic hydrazide to sugarcane at intervals prior to harvesttime. Field experiments were conducted at Río Piedras in northern Puerto Rico and at Colonia Río Grande, between Caguas and Gurabo, in east-central Puerto Rico. Daily fluctuations in Brix, polarization, purity, and available 96° sugar percent cane were followed for 46- and 72-day periods, respectively. No significant differences were observed between the mean available 96° sugar percent cane that could be ascribed to treatments. Seasonal variations and variations attributable to weather conditions were rather important factors at both locations.

RESUMEN

Se presentan aquí datos sobre el efecto de aplicaciones de 2,4-D y "maleic hydrazide" a intervalos previos a la recolección de la caña. Se establecieron experimentos de campo en Río Piedras, al norte de Puerto Rico, y en la Colonia Río Grande, entre Caguas y Gurabo, en la zona este-central de la Isla. Se estudiaron las fluctuaciones en Brix, polarización, pureza y sacarosa durante períodos de 46 y 72 días, respectivamente. No se registraron diferencias significativas debido al efecto de los tratamientos, entre los valores promedio de sacarosa, en ninguna de las dos localidades. Se ob-

servaron variaciones muy marcadas en ambas localidades debidas a la época de corte de las muestras.

LITERATURE CITED

1. Beauchamp, C. E., Effects of 2,4-D on sugar content of sugarcane, *Sugar J.* **13** (5) 57–70, Oct. 1950; **13**(6) 20–30, Nov. 1950.
2. Currier, H. B., Day, B. E. and Crafts, A. S., Some effects of maleic hydrazide on plants, *Bot. Gaz.* **112**(3) 272–80 1951.
3. De Oliveira, B. D., et al., Expeirmentos para aumentar o teor em sacarose da cana de azúcar, Report of the Brazilian observers on the experiments of Dr. C. E. Beauchamp, *Brazil Azucareiro* **37**(4) 92–6 1951.
4. Loustalot, A., Cruzado, H. J. and Muzik, T. J., The effect of 2,4-D on the sugar content of sugarcane, *Sugar J.* **13**(5) 78 1950.
5. Lugo-López, M. A. and Grant, R., Preharvest foliage sprays of sugarcane with 2,4-D, *J. Agric. Univ. P. R.* **36**(3) 187–93 1952.
6. McIlrath, W. J., Response of the cotton plant to maleic hydrazide, *Am. J. Bot.* **37** 816–19, 1950.
7. Naylor, A. W. and Davis, E. A., Some effects of maleic hydrazide on growth and respiration of representative monocots and dicots, *Proc. Am. Soc. Plant Physiol.* (24th meeting), abstracts p. 13, Dec. 1949.
8. Naylor, A. W. and Davis, E. A., Maleic hydrazide as a plant growth inhibitor, *Bot. Gaz.* **112**(1) 112–26 1950.
9. Peto, F. H., et al., Effects of preharvest sprays of maleic hydrazide on sugar beets,, *Am. Soc. Sugar Beet Tech.*, abstracts p. 4, Salt Lake City, Feb. 1952.
10. Pipes, F., Hormones to increase yield, edit., *Sugar J.* **12**(8) 3 1950.
11. Ririe, D. and Mikkelson, D. S., The effect of maleic hydrazide on sugar beet growth and sucrose content in certain field experiments, *Am. Soc. Sugar Beet Tech.*, abstracts p. 3, Salt Lake City, Feb. 1952.
12. Stout, M., Two years results evaluating effect of preharvest sprays of maleic hydrazide on respiration and spoilage of sugar beets, *Am. Soc. Sugar Beet Tech.*, abstracts p. 4, Salt Lake City, Feb. 1952.
13. Wittwer, S. H. and Hansen, C.M., Progress report on the effects of preharvest foliage sprays of maleic hydrazide on storage losses of sugar beets, paper presented at meeting of Am. Soc. of Sugar Beet Tech., Detroit, Jan. 25, 1951.
14. Wort, D. J., Effect of nonlethal concentrations of 2,4-D on buckwheat, *Plant Physiol.* **26**(1) 50–7 1950.

THE USE OF STREPTOMYCIN (DIHYDROSTREPTOMYCIN SULFATE) IN THE TREATMENT OF FOWL CORYZA OR "MOQUILLO"

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INTRODUCTION

The poultry and egg business in Puerto Rico had an average yearly value of $10,600,000 from 1944 to 1948. Importations of poultry meat and eggs from the United States of America and foreign countries amounted to $3,139,000 in 1949–50.

The need for expansion of the poultry business is apparent when we consider that importations during 1949–50 were valued at over $3,000,000. Diseases of poultry are important among the many obstacles that handicap the business and prevent its expansion. Among the diseases that affect poultry on the Island, coryza or "moquillo" is common and economically important.

NATURE OF "MOQUILLO" AND ITS CONTROL

Beach (1)[2] considered coryza the most common and widespread of all poultry diseases. Certain environmental conditions, such as overcrowding, dampness, poor ventilation, and sudden changes in temperature, aid in its establishment and spread.

The etiological agent of "moquillo" has been determined to be a pleomorphic polar-staining hemophyllic bacillus called *Hemophilus gallinarum*. The disease is remarkably variable in severity and virulence, depending upon the character of the complications and the number of birds affected. The symptoms of coryza include nasal discharge, droopiness and general dejection, diminished appetite or anorexia, swelling of the face and wattles, sinusitis, conjunctivitis, tracheitis, bronchitis, and infection of the air sacs, with gasping and coughing. The birds often become emaciated.

The disease usually has a prolonged course, extending over several weeks, or even months. Mortality may reach 50 percent of the affected birds, and usually results from suffocation (asphyxia) as a result of the involvement of the lower respiratory tract.

Definite diagnosis of coryza, according to Beach (1), requires the determination of transmissibility by contact with healthy birds or alternatively by intranasal inoculation of healthy birds with exudate from affected ones,

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[2] Numbers in parentheses refer to Literature Cited, p. 58.

and the demonstration of *H. gallinarum* under the microscope. "Moquillo" may be confused with other diseases like fowl cholera, laryngotracheitis, and nutritional deficiencies like A-avitaminosis. Transmission and cross-protection tests are often necessary to differentiate between coryza and infectious laryngotracheitis. Microscopic and cultural laboratory methods are frequently required to distinguish "moquillo" from fowl cholera.

Recommendations for the control and treatment of coryza have included segregation and sometimes destruction of affected flocks; disinfection of nasal passages of sick birds with nonirritating substances such as boric acid, menthol, or liquid petrolatum; destruction of severely affected animals; incision and drainage of the sinuses; strict sanitation of utensils and premises; correction of any inadequate housing or managerial practice; and feeding of a 1-percent sulfathiazole mix. Treatment has not been too successful, and birds that recover are regarded as carriers, thus increasing the complexity of control.

Mr. Ramón Rosa Alvarado, an Extension county agent, reported apparent beneficial results from the use of streptomycin injections in a limited number of valuable game-birds. With this information to go on the authors decided to evaluate the possibilities of streptomycin as a treatment for coryza. The first four trials described below were carried out at the Río Piedras Station during July and August 1949. The last two were undertaken at the La Plata (Aibonito) Substation in colony hen houses, during July and August 1951.

EXPERIMENTAL METHODS AND RESULTS WITH STREPTOMYCIN

Trial No. 1

Twelve young birds about 3½ months old, and weighing about 3 pounds each, with clinical symptoms of "moquillo" were paired off in a 6-cage, 3-tier battery. One of the two birds in each cage was subcutaneously injected in the pectoral area with 0.25 gm. of dihydrostreptomycin sulfate in 1 cc. of sterile, distilled water. The second bird of the pair was left in the cage as an infected, untreated control.

Clean, fresh water was kept before the birds at all times; a commercial feed mixture was provided. The battery was washed, disinfected, and sun-dried before putting the birds in, and was cleaned daily during the test.

Observations were made on the birds individually at 24-hour intervals, for 5 days. Each bird was checked for nasal discharge daily, by pressing with the thumb over the nasal openings.

Five of the six birds with coryza which were treated subcutaneously with 0.25 gm. of streptomycin, were found free of nasal discharge 48 hours later. Two of these birds were negative 24 hours after injection. While all six

control birds remained infected, 83.33 percent of the treated birds responded favorably, even in the presence of infected battery mates throughout the experimental period.

This preliminary trial definitely established the value of streptomycin in controlling fowl coryza, corroborating results informally reported to us. Further trials were made to determine the proper dosage and the best method of administering it.

Trial No. 2

Forty-eight young birds about 3½ months old and weighing about 3 pounds each were placed in groups of six in an 8-cage, 4-tier battery which had been washed, disinfected, and sun-dried before use. Management was as outlined for trial No. 1. All 48 birds showed clinical symptoms of coryza. Of each group of six birds, two were injected subcutaneously with 0.10 gm. of dihydrostreptomycin sulfate in 1 cc. of sterile, distilled water; two were similarly injected with 0.05 gm. of the antibiotic; two were left as infected, untreated controls. Injections were made in the pectoral area.

Observations were made on the individual birds twice daily for 4 days, starting 18 hours after injection. Four of the sixteen infected controls died from coryza during the experimental period; two died within 48 hours after the start of the experiment, and the other two within 76 hours. All of the surviving 12 controls remained infected. Two of the sixteen birds given subcutaneous doses of 0.10 gm. of streptomycin and one of the sixteen birds given subcutaneous doses of 0.05 gm. of streptomycin, were free from nasal discharge and other symptoms of coryza, and were considered cured.

The criterion established for a "cure" was the disappearance of the characteristically offensive nasal discharge for a minimal period of 48 consecutive hours. Thus, 12.5 percent of the birds dosed with 0.10 gm. were regarded as cured as compared with only 6.3 percent (1 out of 16 birds) of those dosed with 0.05 gm.

Trial No. 3

Forty-four young birds showing symptoms of "moquillo" were distributed in four groups of five birds, and four groups of six birds each, in an 8-cage, 4-tier battery. Two birds in each group were subcutaneously injected in the pectoral area with 0.10 gm. of dihydrostreptomycin sulfate in 1 cc. of sterile, distilled water; two other birds per group were similarly injected with 0.05 gm. of the antibiotic. In four groups, two infected, untreated birds were left as controls, whereas only one control bird per group was left in the other four groups. Handling and management were as outlined above for previous trials.

Observations were made on the individual birds twice daily for 6.5 days, starting 24 hours post-injection. One of the twelve infected controls died from coryza during the observation period and within 48 hours after the start of the experiment. The 11 surviving controls were still infected at the end of the experiment.

Three of the sixteen birds (18.7 percent) injected subcutaneously with individual 0.10-gm. doses of streptomycin apparently remained free from coryza. Three of the sixteen birds (18.7 percent) dosed with 0.05 gm. also were regarded as cured.

Trial No. 4

Forty-eight young birds with clinical signs of "moquillo" were housed, handled, and managed as outlined for the previous trials. The birds were placed six to a group, two being infected, untreated controls, two being treated with 0.10 gm. of dihydrostreptomycin sulfate, and two with 0.05 gm. as outlined above. Observations were made on the individual birds twice daily for 15 days, starting 24 hours post-injection. During this observation period of 15 days, 4 of the 16 infected controls died from coryza. None of the surviving controls recovered from the infection.

Six of the sixteen birds (37.5 percent) treated subcutaneously with 0.10 gm. of streptomycin recovered from coryza during the 15 day observation period. Two of the remaining ten birds treated with 0.10 gm. died from coryza. Only four of the sixteen birds (25 percent) in the 0.05-gm. group recovered from coryza.

Trial No. 5

One hundred and forty birds with clinical symptoms of coryza were divided into four groups of 30, 35, 35, and 40 individuals each. Each group was subdivided into infected, untreated controls, and birds treated with 0.10, 0.15, 0.20, and 0.25 gm. of dihydrostreptomycin sulfate. Each individual dose was dissolved in 1-cc. of sterile, distilled water. Infected controls were injected with 1 cc. of unmedicated, sterile distilled water. All injections were made intramuscularly in the pectoral area. Twenty-eight birds were included in each dosage-treatment and control group

Observations were made on individual birds at 24-hour intervals, for 21 days, starting 1 day after injection. Handling and management followed the pattern outlined for previous trials. Eight of the twenty-eight infected control birds (28.6 percent) were considered negative at some time during the 21-day observation period. Seven of the eight negative birds were found in one hen house; one of these negative birds died later on during the observation period. We have no plausible explanation for these apparently spontaneous recoveries. The remaining 20 birds in the

control group carried the infectious coryza throughout the experimental period.

Twenty-six of the twenty-eight birds (92.9 percent) treated with single intramuscular injections of 0.10 gm. of streptomycin were apparently freed from coryza. One of the negative birds died during the 21-day observation period. A single intramuscular injection of 0.15 gm. of streptomycin was successful in curing 21 of the 28 birds so treated (75 percent). One of the seven birds in this group that failed to respond to the treatment died from

TABLE 1.—*Effectiveness of streptomycin in controlling coryza or "moquillo" in chickens, by dosage, and method of administration*

Trial No.	Dosage used—		Infected birds used and results				
	Subcutaneously	Intramuscularly	Total	Treated	Control	Cured	
	Grams	*Grams*	*Number*	*Number*	*Number*	*Number*	*Percent*
1	0.25	....	12	6	6	5	83.3
2	.10	....	48	16	16[1]	2	12.5
	.05	....		16		1	6.3
3	.10	....	43	16	11[2]	3	18.7
	.05	....		16		3	18.7
4	.10	....	48	16[3]	16[4]	6	37.5
	.05	....		16		4	25.0
	....	0.10	140	28[5]	28[5]	26	92.9
	....	.15		28[5]		21	75.0
	....	.20		28		27	96.4
5	....	.25		28		24	85.7
6	....	.10	697	697		675	97.0

[1] 4 birds died during observation period.
[2] 1 control bird died during observation period.
[3] 2 birds died during observation period.
[4] 4 control birds died during observation period.
[5] 1 of the treated and 1 of the control birds died during observation period.

coryza during the observation period. Twenty-seven of the twenty-eight birds (96.4 percent) injected intramuscularly with 0.20 gm. of streptomycin apparently recovered from the coryza infection during the observation period, while 24 of the 28 birds similarly treated with 0.25-gm. doses (85.7 percent) responded favorably.

One hundred and six birds (75.5 percent of the 140 in the trial) were regarded as "cured" at some time during the experimental period, eight of these being in the untreated, infected control group.

One hundred and twelve birds were treated at one of the four dosage levels of streptomycin used. The antibiotic apparently cleared up infectious coryza in 87.5 percent of them (98 birds).

Trial No. 6

A total of 697 cockerels and pullets with clinical signs of coryza, grouped in colony houses, was handled and managed as outlined above for previous trials. Each bird was injected with 0.10 gm. of dihydrostreptomycin sulfate in 1 cc. of sterile, distilled water. Injections were made intramuscularly in the pectoral region. All the birds were injected, none being left as controls.

Observations on individual birds were made 3 and 6 days after injection. Observations made 3 days after treatment revealed that 663 of the birds were free from coryza. A second observation made 3 days later showed that a total of 675 (97 percent) of the 697 birds had apparently recovered from the infection.

Results from all trials

For the convenience of the reader the results from all six trials to determine the effectiveness of streptomycin in the control of chicken coryza are presented in table 1.

SUMMARY AND CONCLUSIONS

We are of the opinion that the use of streptomycin injections is definitely benefitial in controlling infectious coryza of chickens.

Seventy of the seventy-eight infected, untreated control birds did not recover from coryza; 10 of these control birds died from coryza infection during the observation periods; 8 birds in the control group made an apparently spontaneous recovery for which we have no valid explanation.

Whereas any treatment with streptomycin injection proved better than no treatment, the lowest dose used in these trials, i.e., 0.05 gm. subcutaneously per bird, did not seem to be effective in a large proportion of the birds treated under our experimental conditions.

A single 0.10-gm. dose of streptomycin per bird proved to be more effective in curing and checking coryza than the 0.05-gm. dose. The effectiveness of the 0.10-gm. dose used subcutaneously, varied from 12.5 to 37.5 percent when the coryza-infected birds were kept in batteries in the presence of infected, untreated controls.

When the single 0.10-gm. dose was injected intramuscularly, its effectiveness increased to 92.9 percent, even in the presence of infected, untreated controls in the same hen house.

The effectiveness of the 0.15-gm. intramuscular dose was 75 percent.

The highest effectiveness, 96.4 percent, was noted when a single intramuscular 0.20-gm. dose was used per bird.

The 0.25-gm. dose had an effectiveness of 83.3 percent when injected subcutaneously, and 85.7 percent intramuscularly.

We believe that the cost of the higher streptomycin dosage-levels (0.20 and 0.25 gm.) may preclude their extensive use in commercial poultry flocks, especially so when their respective effectiveness is not substantially (significantly) greater than that of lower, cheaper streptomycin doses.

The use of a single, intramuscular dose of 0.10 gm. of streptomycin per bird affected seems to be an economical, efficient, and reliable means for the control of infectious coryza or "moquillo" of poultry.

RESUMEN

Las inyecciones de estreptomicina son eficaces para controlar el "moquillo" de las aves.

Las aves que se trataron con la estreptomicina mejoraron o curaron del "moquillo" en una proporción mayor que las que se dejaron sin administrarle la droga. Sin embargo, es bueno apuntar, que la concentración de 0.05 gramo de estreptomicina, la más baja en los ensayos, aplicada subcutáneamente a cada ave, dejó de surtir los efectos de curación esperados.

Cuando se inyectó la estreptomicina en concentraciones de 0.10, 0.15, 0.20, y 0.25 gramo por ave, la eficacia de la droga en contra de la enfermedad fué de 92.9, 75.0, 96.4 y 85.7 porciento, respectivamente.

Las inyecciones intramusculares fueron más eficaces que las subcutáneas.

De acuerdo con los resultados, el aplicar una inyección intramuscular de 0.10 gramo de estreptomicina por ave enferma, es un método económico y casi seguro para controlar el "moquillo" aviar.

LITERATURE CITED

1. Beach, J. R., Infectious Coryza, pp. 303–7, Diseases of Poultry, by Biester, H. E., and De Vries, Louis, The Collegiate Press, Inc., Ames, Iowa, 1944.

THE VALUE OF GRASS SILAGE FOR FEEDING DAIRY COWS IN PUERTO RICO

J. I. Cabrera and L. Rivera-Brenes[1]

INTRODUCTION

For a great many years the advantages of preserving green forage crops for winter and drought seasons has been recognized. As early as 1786 (1)[2] history records that the Italians preserved green crops for their animals by storing them in pits under the ground. The French and English are known to have stored green crops a century and a half ago. In the United States, credit is given to Fred L. Hatch for building the first silo on his farm, in 1873. In Puerto Rico, D. W. May (2) erected the first silo at the Federal Experiment Station at Mayagüez. For some time after farmers were slow to follow his example and it is only in comparatively recent years that silos have been in use throughout the southern and northern coasts of the Island.

REVIEW OF LITERATURE

The literature on the nutritive value of silage and its preparation is very extensive and widely known. May (2) failed in preparing Para grass (*Panicum purpurascens*), Guinea grass (*Panicum maximum*), and cane tops (*Sacharum officinarum*) silage. The cane-top silage was sour probably because of its condition when put into the silo. Rivera Brenes (3) et al., published the first work done at this Station on the preparation of silage. They laid the foundations for the work reported here. It was concluded that Para grass, Merker grass (*Pennisetum purpurascens* va. Merkerii), and cane tops made a rather good silage. Better quality silage was obtained when using Merker grass than when using either of the other two roughages.

EXPERIMENTAL PROCEDURE

Feeding trials were conducted to determine the value of Merker grass at two stages of maturity, Para grass with 5 or 10 percent of molasses, and immature whole sugarcane as silage. These trials covered a period of 3 years starting January 1947. Usually these silages were compared with Merker grass fed as soilage.

Silage was prepared according to the availability of the forages and other

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[2] Numbers in parentheses refer to Literature Cited, p. 73.

facilities. Enough silage was made at a time to run a feeding trial. Molasses was generally used as a preservative.

The animals used came from our experimental herd and were mostly grades. These cows were grouped taking in consideration their production and stage of lactation.

The direct and double-reversal methods of experimentation were used in comparing the different roughages studied.

Prefeeding periods of from 5 to 7 days were followed by experimental periods of 21 to 28 days. During the prefeeding period the cows were weighed and the concentrate rations adjusted. The concentrate ration

TABLE 1.—*Proximate analyses of the various roughages compared in feeding experiments with dairy cows*

Roughage studied	Samples	Dry matter	Ash	Protein	Fat	Fiber	N. F. E.
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Immature Merker grass	36	18.05	9.34	6.08	1.45	35.84	47.28
Mature Merker grass	19	26.94	6.80	5.93	1.97	33.80	50.68
Mature Para grass	5	30.60	6.03	7.59	2.09	31.42	52.87
Immature Merker grass silage	11	20.10	12.32	5.85	2.04	29.17	50.61
Mature Merker grass silage	20	27.11	12.28	6.25	2.29	31.22	47.48
Para grass silage, 5-percent molasses	5	21.71	15.54	7.08	1.31	30.41	45.64
Para grass silage, 10-percent molasses	5	29.53	18.24	8.42	1.39	24.60	47.38
Merker-kudzu grass	6	20.21	8.80	6.35	1.58	38.27	45.00
Merker-kudzu silage	6	24.82	9.37	4.71	1.39	35.60	48.86
Immature sugarcane	3	21.54	8.04	4.31	1.42	31.90	54.32
Immature sugarcane silage	20	20.54	10.73	5.00	1.44	33.63	49.19

was left unchanged to render constant the quantity of nutrients derived from it throughout the entire experimental period. This ration was calculated on a production period of 10 days prior to the beginning of the trial. Daily concentrate and roughage consumption, as well as milk-production records, were kept throughout. The roughage was fed ad libitum and the concentrate at a ratio of 1 pound per 2½ pounds of milk produced. All animals used were weighed at the beginning and at the end of each experimental period.

The following feeding trials were performed: Mature Merker grass silage vs. Para grass soilage; immature Merker grass silage vs. mature Merker grass silage, 34 days difference in age; immature Merker grass silage vs. mature Merker grass silage vs. mature Merker grass; Para grass silage plus 5 or 10 percent of molasses vs. mature Merker grass soilage; mature Merker grass silage vs. immature Merker grass soilage; mature

Merker-kudzu grass silage vs. mature Merker grass; and immature sugarcane vs. mature Merker grass. Table 1 shows the proximate analyses of the roughages compared.

TABLE 2.—*Milk production of cows on Para grass and on Merker grass silage*[1]

Cow	Base period	Test period	Difference
Group 1: Cows receiving Para grass (Malojillo)			
	Pounds	*Pounds*	*Pounds*
Jewel	27.0	25.5	1.5
Walker Jr.	29.2	27.2	2.0
Pontiac	26.0	24.2	1.8
Princesa	24.2	22.7	1.5
Rosalinda	11.6	8.5	3.1
Queen	10.8	11.1	−.3
Denia	16.9	15.8	1.1
Nana	13.7	11.6	2.1
Nellie Jr.	13.7	12.1	1.6
Enanita	11.5	9.0	2.5
Redonda	17.7	13.9	3.8
Carmen	10.2	8.2	2.0
Average	17.71	15.81	1.90
Group 2: Cows receiving Merker silage			
Lupe	34.2	32.2	2.0
Luisa 32	27.4	26.6	.8
Nellie	25.8	24.5	1.3
Kassandra	20.6	19.5	1.1
María Luisa	15.9	14.7	1.2
Canaria	11.9	12.2	−.3
Angelina	17.3	15.6	1.7
Berta	13.4	13.9	−.5
Mulata	12.4	13.0	−.6
Nena	13.6	13.3	.3
Guinea	13.3	14.4	−1.1
Yolanda	12.8	11.1	1.7
Average	18.22	17.58	.64

[1] Difference between groups in decline of production, 1.90 − 0.64 = 1.26 lbs. of milk per day.

Mature Merker Grass Silage Vs. Mature Para Grass Soilage

Two groups of 12 cows each were used in this feeding trial. All of them were on Para grass soilage for about 4 weeks prior to the start of the com-

parison. The silage group had a prefeeding period of 6 days. Table 2 contains the milk-production data and table 3 the data on forage consumption for the test period.

TABLE 3.—*Forage consumption of cows on Para grass and on Merker silage during test period*

Cow	Average per day	Per 100 lbs. of body weight
Group 1: Cows receiving Para grass		
	Pounds	*Pounds*
Jewel	89.0	6.89
Walker Jr.	72.3	7.37
Pontiac	86.6	7.59
Princesa	82.8	7.39
Rosalinda	55.5	6.09
Queen	93.9	6.61
Denia	54.4	7.15
Nana	62.5	7.62
Nellie Jr.	76.4	8.21
Enantia	55.6	6.61
Redonda	50.0	5.95
Carmen	63.1	8.64
Average	70.2	7.18
Group 2: Cows receiving Merker silage		
Lupe	59.2	6.04
Luisa 32	67.7	6.57
Nellie	80.7	7.27
Kassandra	66.7	7.32
María Luisa	60.0	6.45
Canaria	79.8	7.74
Angelina	62.3	6.48
Berta	59.1	7.29
Mulata	60.4	8.05
Nena	60.2	7.08
Guinea	67.7	7.87
Yolanda	49.3	5.41
Average	64.4	6.96

The analysis of variance of the differences in production between the base and test periods is shown below. The significant mean square for groups indicates a real superiority of the silage.

Source of variance	*DF*	*Mean square*	*F*
Groups	1	9.50	8.96
Within groups	22	1.06	
	23		

Difference between groups, 1.26 ± .42

The results of this short trial indicate that the mature Merker grass silage was a better forage for lactating cows than the Para grass with which it was compared. The difference might have been greater if the test period had been longer.

The cows on the silage consumed 1.64 pounds of dry matter per 100 pounds of body weight as compared with 2.19 pounds of dry matter per 100 pounds of body weight for the group on soilage. Milk production on the silage was considered satisfactory, particularly since the feeding period was hardly long enough for the animals to become accustomed to the silage; production was maintained better than with Para grass.

Immature Merker Grass Silage Vs. Mature Merker Grass Silage

A grass field was selected to make the silage for this trial. The immature grass was cut when 60 days old and the mature 34 days later. In this feeding trial two groups of five cows each were used. Direct comparison of the production of the cows during the feeding period was made. Table 4 shows the average daily production of the two groups, while table 5 shows the forage consumption during the experimental periods.

The analysis of variance of the difference in production, as shown below indicates that there was no significant difference between the two silages compared.

Source of variation	*DF*	*Mean squares*	*F value*
Groups	1	0.3881	0.1259
Within groups	8	3.083	

There was a highly significant difference between the dry matter consumed by the cows on the mature Merker grass silage and that consumed by the cows on the immature Merker grass silage, (see table 5) as shown in the analysis of variance presented below.

Source of variation	*DF*	*Mean squares*	*F value*
Group	1	0.1871	7.65
Within groups	8	0.02476	

Immature Merker Grass Silage Vs. Mature Merker Grass Silage Vs. Mature Merker Grass Soilage

The silages used in this trial were prepared during September and October 1948. The grass used to prepare them came from the same field which

TABLE 4.—*Milk production per day of cows receiving immature and mature Merker grass silage*

Cow	Base period	Test period	Difference
Group 1: Cows receiving immature Merker silage			
	Pounds	*Pounds*	*Pounds*
María	13.02	14.33	1.31
Coamo	11.70	13.42	1.72
Soroca	25.38	25.73	.35
Luisa	13.07	11.24	−1.83
Walker Jr.	10.36	10.20	−.16
Average	14.70	14.98	−.28
Group 2: Cows receiving mature Merker silage			
Carmelita	16.62	15.33	−1.29
Rivera	17.51	17.97	.46
Clio	17.49	20.57	3.08
Mercedes	18.31	18.69	.38
Lupe	17.72	15.35	−2.37
Average	17.53	17.58	.05

TABLE 5.—*Forage consumption during test period of cows on immature and mature Merker grass silage*

Cow	Average per day	Per 100 lbs. body weight	Dry matter per 100 lbs. body weight
Group 1: Cows receiving immature Merker grass silage			
	Pounds	*Pounds*	*Pounds*
María	76.11	8.5	1.7
Coamo	70.28	8.6	1.8
Soroca	75.00	8.9	1.8
Luisa	69.30	7.6	1.6
Walker Jr.	75.30	6.8	1.4
Average	73.20	8.1	1.7
Group 2: Cows receiving mature Merker silage			
Carmelita	54.86	6.3	1.8
Rivera	56.00	6.8	1.9
Clio	70.03	7.7	2.1
Mercedes	63.97	7.0	2.0
Lupe	72.50	6.7	1.9
Average	63.47	6.9	1.9

was cut previously for the earlier Merker grass trial. The silage phase of this trial was a repetition of the earlier trial.

Table 6 shows the differences in milk production for the three groups of cows receiving the different roughages.

TABLE 6.—*Difference in average daily production of cows receiving immature and mature Merker grass silage and mature Merker grass*

Immature Merker silage		Mature Merker silage		Mature Merker grass	
Cow	Production	Cow	Production	Cow	Production
	Pounds		*Pounds*		*Pounds*
Pipiola	2.81	Dulcy	1.87	Tequila	6.02
Mercedita	.74	Libertad	4.98	Laura	4.93
Nélida	3.12	Dolly	2.82	Inés	4.31
S. S. 17	1.81	Redonda Jr.	3.14	Candy	4.73
Gloria	.92	Angelina	1.60	Geña Jr.	4.73
Carmelita	2.60	Nellie	1.92	Bola	1.31
Berta	1.85	Bonita	.75	Soroca	4.45
María	1.52	Dunure Jr.	.25	Carmen	1.47
Total	11.95	Total	16.83	Total	31.95

The analysis of variance of the above differences is shown below:

Source of variance	*DF*	*SS*	*Mean square*	*F value*
Total				
Groups	2	56.25	28.125	8.22
Within groups	21	71.84	3.42	

There was a significant difference in production between the groups. The value for the comparison of the three roughages was as follows: Immature Merker grass silage and mature Merker grass silage 1.93*; immature Merker grass silage and mature Merker grass 3.807**; mature Merker grass silage and mature Merker grass 2.21*.

These values indicate that the immature Merker grass silage was statistically superior to mature Merker grass silage at the 5 percent point. On the other hand the mature Merker silage ranked superior at the 5 percent point to the mature Merker grass fed green. The immature Merker grass silage was superior to the mature grass soilage at the 1 percent level.

Although the results obtained from the silages in this trial were differ ent from those obtained in the earlier one, after pooling the data the difference in production was not significant.

The analysis of variance for the production of cows on immature and mature Merker grass silage (pooled data) is shown below:

Source of variance	*DF*	*Mean square*	*F value*	
Group	1	6.1753	6.1753	1.40
Error	24	105.5876	4.40	

There was no significant difference in the analyses of the constituents of the three roughages studied.

TABLE 7.—*Average milk production per day of cows on Para grass silage containing 5-and-10 percent of molasses, and on mature Merker grass fed green during base and test periods*

Cow	Base period	Test period	Difference
Group 1: Cows on Para grass silage with 5 percent of molasses			
	Pounds	*Pounds*	*Pounds*
Princesa	38.96	33.75	−5.21
Ingrid	18.57	13.94	−4.62
Gacha	14.02	9.96	−4.06
Nena	13.12	10.56	−2.56
Nellie Jr.	18.75	13.01	−5.74
Esmeralda	16.06	14.25	−1.81
Average	19.91	15.91	−4.00
Group 2: Cows on Para grass silage with 10 percent of molasses			
Hebilla	13.01	10.07	−2.94
Kassandra	16.68	12.43	−4.26
Walker Jr.	38.46	36.06	−2.40
Mirta	18.84	15.46	−3.38
Luisa 32	29.72	26.54	−3.18
Canaria	13.61	9.41	−4.20
Average	21.72	18.33	−3.39
Group 3: Cows on mature Merker grass fed green			
Carmen	26.25	27.68	1.03
Denia	19.27	20.09	.82
Walker	31.52	33.17	1.65
Lupe	31.05	32.70	1.68
Dunure Jr.	42.60	45.14	2.54
Vera	13.30	15.48	2.18
Average	27.40	29.04	1.65

Para Grass Silage With 5- and 10-Percent Molasses Vs. Mature Merker Grass

In this trial the production of the cows during the test period on the three roughages was compared with a lactating period prior to the test period equally long in days, called the base period. The three groups of

animals were groups fed. Table 7 shows the average daily production of the cows during the experimental period as compared to the base period. Observe the marked difference in the reaction of the cows to the three roughages.

Using the difference in the production obtained by comparing the test period with the base period it was found that the difference among the treatments was highly significant as shown below. Merker grass fed green was superior to Para grass silage with 5 or 10 percent of molasses. There was no significant difference in the production of the cows receiving the Para grass silages.

The analysis of variance of the difference in average daily milk production between the base and the test period is shown below:

Source of variance	*DF*	*Mean square*	*F value*
Group	2	57.725	52.35
Within groups	15	1.102	

The average dry-matter consumption for the three groups was as follows: Group 1: Para grass silage with 5 percent of molasses, 1.63 pounds of dry matter per 100 pounds of body weight; Group 2: Para grass silage with 10 percent of molasses, 1.88 pounds of dry matter per 100 pounds of body weight; Group 3: Merker grass fed green, 2.01 pounds of dry matter per 100 pounds of body weight.

In spite of the molasses in Para grass silages, these were the poorest in odor, color, etc. The difference in consumption between the Merker grass soilage and the silages was probably because of its greater palatability. All the animals maintained their weight during the experiment.

Mature Merker Grass Silage Vs. Immature Merker Grass

Approximately 10 percent of molasses was used in the preparation of this silage. The grass fed was in its early-maturing stages containing an average of 82.60 percent of moisture. Table 8 shows the average milk production for the experimental period as compared with a base period.

The analysis of variance shown below for the milk production data indicates that Merker grass fed as silage was statistically superior to immature Merker grass silage under our experimental conditions.

The analysis of variance for milk production is shown below:

Source of variance	*DF*	*Mean Square*	*F value*
Group	1	12.3963	20.67
Within groups	12	.5996	

The two groups were group-fed and they averaged 1.98 pounds of dry matter per 100 pounds of body weight; this shows that the silage was as palatable for both groups as the green forage.

TABLE 8.—*Average milk production per day of cows on Para grass silage containing 5-and-10 percent of molasses, and on mature Merker grass fed green during base and test periods*

Cow	Base period	Test period	Difference
	Group 1: Cows receiving mature merker grass silage		
	Pounds	*Pounds*	*Pounds*
Princesa	27.46	28.46	.80
Ingrid	12.92	13.64	.72
Gacha	8.97	10.24	1.27
Nellie Jr.	13.46	13.54	.08
Carmen	18.92	19.10	.18
Hebilla	9.16	9.40	.24
Kassandra	12.20	11.99	−.21
Average	14.73	15.17	.44
	Group 2: Cows receiving immature Merker grass		
Denia	14.64	13.60	−1.04
Walker	24.40	22.76	−1.64
Esmeralda	12.58	11.36	−1.22
Rosalinda	6.74	5.27	−1.47
Dunure Jr.	30.53	30.80	.27
Canaria	12.54	9.60	−2.94
Enanita	6.29	5.52	.77
Average	15.39	14.13	−1.25

TABLE 9.—*Average daily production of the cows on Merker-kudzu silage and on mature Merker grass*

Merker-kudzu silage		Merker grass	
Cow	Production	Cow	Production
	Pounds		*Pounds*
María	8.90	Toledo Jr.	5.31
Gloria	20.48	India Jr.	8.16
Lupe	3.12	Yolanda	5.19
Rivera	5.87	Sisa	7.76
Gaviota	6.76	Paloma	7.53
Carmelita	13.51	Nellie	14.75
Carmen	6.18	Dunure Jr.	8.44
Berta	4.99	Rio Piedras Jr.	4.56
Soroca	14.67	Ida	11.24
Gachita	9.00	Cleo	8.88
Aura	8.46	Lila Jr.	4.70
María Luisa	5.60	Correa	5.69
Total	107.44	Total	90.20

Comparison of Merker-Kudzu Silage and Merker Grass

The silage was prepared during July 1948. The Merker grass was mature. Merker-kudzu mixture makes a palatable silage and was readily

TABLE 10.—*Average daily production and the statistical arrangement for the calculation of the experiment with cows fed mature Merker grass and sugarcane silage*

Cow	Results for experimental periods—					
	1	2	3	1 x 3	2 (2)	*D*
Mature Merker grass						
	Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Gachita	25.62	22.35	21.15	46.77	44.70	2.06
Kassandra	35.88	31.78	27.40	63.28	63.56	−0.28
Denia	27.15	23.94	22.37	49.52	47.88	1.64
Nélida	12.26	11.31	10.07	22.33	22.62	−0.29
Mercedes	20.31	21.27	19.15	39.46	42.54	−3.08
Luna	13.23	13.77	13.02	26.25	27.54	−1.29
Sum						−1.24
Sugarcane silage						
Sisa	25.08	14.13	15.65	40.73	28.26	12.47
Dolly	19.31	14.55	16.52	35.83	29.10	6.73
María	36.36	29.13	32.37	68.73	58.26	10.47
Berta	20.30	16.21	17.35	37.65	32.42	5.23
Dulcy	17.69	14.42	17.34	35.03	28.84	6.19
Josefina	14.76	10.94	13.29	28.05	21.88	6.17
Sum						47.26

consumed by the cows. Table 9 shows the average daily production of the cows in both groups.

Source of variance	*DF*	*SS*	*Mean square*	*F value*
Treatments	1	11.48	11.48	0.6632
Error	22	380.87	17.31	

The analysis of variance as shown indicates that there was no significant difference in the production of the cows on Merker-kudzu silage and Merker grass fed green. This was probably because the proportion of kudzu in the mixture was very low making little difference in the nutritive value.

The forage consumption study indicates that the groups of cows on the Merker-kudzu silage consumed 1.61 pounds of dry matter per 100 pounds, as compared with 1.45 pounds of dry matter per 100 pounds of weight for the groups on Merker grass.

Both groups of cows maintained their body weight throughout the experimental period.

Comparison of Sugarcane Silage Vs. Merker Grass

The silage used in this feeding trial was prepared during the early days of September 1949. The sugarcane used was from 4 to 5 months old, in the usual way, chopped through a silage chopper, and blown into two tower silos. The average moisture content was 79.70 percent.

The mature Merker grass used came from our fields with an average of 71.28 percent moisture content. The whole sugarcane plant makes a rather palatable silage; farmers should take the advantage of this and the heavy tonnage it produces. The high carbohydrate content serves as a good preservative. Table 10 gives the results.

The statistical analysis of the milk production of the different groups indicated that there was a highly significant difference in the production in favor of the group receiving the immature sugarcane silage.

The statistical analysis of the dry-matter consumption per 100 pounds of body weight indicates that the cows on the immature sugarcane silage consumed less (1.49 pounds) than the cows on mature Merker grass (1.98 pounds).

The cows in both groups maintained their body weight throughout the experimental periods.

The results obtained indicate that immature sugarcane silage is a good source of roughage for dairy cows.

SUMMARY AND CONCLUSIONS

A series of feeding trials comparing mature Merker grass silage vs. mature Para grass soilage; immature Merker grass silage vs. mature Merker grass silage; immature Merker grass silage vs. mature Merker grass silage vs. mature Merker grass soilage; mature Para grass silage with 5 or 10 percent of molasses vs. mature Merker grass; mature Merker grass silage vs. immature Merker grass soilage; mature Merker-kudzu grass silage vs. mature Merker grass; and immature sugarcane silage vs. mature Merker grass soilage, were conducted during the period between January 1947 and January 1950. The purpose was to determine the value of the above roughages as silage.

A summary of the proximate analyses of the roughages and silages used is presented.

The following are the conclusions obtained from these trials.

1. Mature Merker grass silage was a more satisfactory source of forage for lactating cows than mature Para grass soilage.

2. The cows on the mature Para grass silage consumed as much as 1.64

pounds of dry matter per 100 pounds of body weight as compared to 2.19 pounds of dry matter per 100 pounds of body weight of the mature Merker grass soilage.

3. There was no significant difference in the production of cows receiving immature Merker grass silage and that of the cows receiving mature Merker grass silage. When the experiment was repeated there was a difference in production in favor of the immature grass silage but, after pooling the data, the difference between the two silages was not significant.

4. There was a highly significant difference between the dry matter consumed by the cows on mature Merker grass silage with 1.92 pounds per 100 pounds of body weight as compared with 1.651 pounds per 100 pounds of body weight for the immature Merker grass silage.

5. There was a highly significant difference between immature Merker grass silage and mature Merker grass soilage and a significant difference between mature Merker grass silage and mature Merker grass soilage.

6. There were no significant differences among the analyses of the constituents of the above three roughages.

7. There was a highly significant difference in the production of the cows on mature Merker grass soilage as compared to that of the cows on mature Para grass silage with 5 or 10 percent of molasses added.

8. There was no significant difference between the production of the cows on Para grass silage with 5 or 10 percent of molasses.

9. The dry-matter consumption for the cows on Para grass silage with 5 percent of molasses was 1.63 pounds per 100 pounds of body weight compared to 1.88 pounds per 100 pounds of body weight for the cows on Para grass silage with 10 percent of molasses, and 2.01 pounds per 100 pounds of body weight for the cows on mature Merker grass fed green.

10. The difference in milk production for the cows on mature Merker grass silage was highly significant when compared to that of the immature Merker soilage group.

11. Both groups consumed an average of 1.98 pounds of dry matter per 100 pounds of body weight.

12. There was no significant difference in milk production of the cows on Merker-kudzu silage and Merker grass fed green.

13. The cows on Merker-kudzu silage consumed an average of 1.61 pounds of dry matter per 100 pounds of body weight consumed by the group of cows on Merker grass.

14. There was a highly significant difference in the production of the cows receiving immature sugarcane silage as compared to that of the cows receiving mature Merker grass.

15. Cows on immature sugarcane silage consumed less dry matter (1.49 pounds) per 100 pounds of body weight than the cows on mature Merker

grass which consumed 1.98 pounds of dry matter per 100 pounds of body weight.

16. Merker grass and young sugarcane silages are good sources of roughage for dairy cows. They are still more important during prolonged dry periods when pastures are not available and also when good soilage grasses cannot be obtained.

RESUMEN Y CONCLUSIONES

Este estudio incluye los datos de una serie de experimentos sobre la alimentación del ganado lechero, obtenidos de los siguientes tratamientos:

1. Ensilaje de yerba Merker madura vs. yerba Pará cortada y madura.
2. Ensilaje de yerba nueva vs. ensilaje de yerba Merker madura vs. yerba Merker cortada madura.
3. Ensilaje de yerba Pará con 5 ó 10 por ciento de miel vs. yerba Merker cortada madura.
4. Ensilaje de yerba Merker madura vs. yerba Merker cortada nueva.
5. Ensilaje de la asociación Merker-kudzú vs. yerba Merker cortada madura.
6. Ensilaje de caña de azúcar nueva vs. yerba Merker cortada madura.

Todos los experimentos se llevaron a cabo durante el período comprendido entre enero, 1947 y enero, 1950.

Los resultados y conclusiones se compendian como sigue:

1. Para las vacas en lactancia, el ensilaje de yerba Merker madura fué mejor fuente de forraje que la yerba Pará cortada madura.
2. Las vacas, en el tratamiento con ensilaje de yerba Pará madura, consumieron hasta 1.64 libras de materia seca por cada 100 libras de peso, y las del tratamiento con la yerba Merker cortada madura 2.19.
3. No hubo diferencia significativa en la producción de leche de las vacas comprendidas en el tratamiento con ensilaje de Merker nueva. Cuando se repitió el experimento, hubo alguna diferencia a favor del ensilaje de Merker nueva, pero después de estudiar los datos en conjunto, esta diferencia entre ambos tratamientos resultó insignificante.
4. Hubo una diferencia altamente significativa. Con relación a la materia seca consumida por las vacas, a razón de 100 libras de peso, entre los tratamientos con ensilaje de Merker madura y el ensilaje con Merker nueva que alcanzó a 1.92 y 1.65 libras, respectivamente.
5. Hubo una diferencia altamente significativa entre el tratamiento con el ensilaje de Merker nueva y el de Merker cortada nueva y sólo significativa entre el de ensilaje de Merker madura y la Merker cortada madura.
6. No hubo diferencias significativas entre los elementos nutritivos de los forrajes usados.
7. Hubo una diferencia altamente significativa en la producción de leche

de las vacas comprendidas en el tratamiento con la yerba Merker cortada madura, al compararse con las que consumieron ensilaje de la yerba Pará, al cual, se le añadió 5 ó 10 por ciento de miel.

8. No hubo diferencia significativa entre la producción de leche de las vacas en el tratamiento con el ensilaje de yerba Pará, cuando se le añadió 5 ó 10 por ciento de miel.

9. El consumo de materia seca por las vacas, en el tratamiento con ensilaje de Pará al cual se le añadió el 5 por ciento de miel, fué 1.63 libras por 100 libras de peso; de 1.88 libras en el tratamiento con ensilaje de yerba Pará, con el 10 por ciento de miel; y de 2.01 libras para las vacas en el tratamiento con yerba Merker cortada madura.

10. La diferencia en la producción de leche de las vacas en el tratamiento con ensilaje de yerba Merker cortada madura, fué altamente significativa cuando se comparó con el del tratamiento con yerba Merker cortada nueva.

11. En ambos casos anteriores, las vacas consumieron, en promedio, 1.97 libras de materia seca por cada 100 libras de peso.

12. No hubo diferencia significativa en la producción de leche de las vacas, entre el tratamiento con el ensilaje de la asociación Merker-kudzú y el tratamiento de yerba Merker cortada madura.

13. Las vacas en el tratamiento con el ensilaje Merker-kudzú, consumieron en promedio, 1.62 libras más de materia seca por 100 libras de peso, que las vacas en el tratamiento con yerba Merker cortada madura.

14. Hubo una diferencia altamente significativa en la producción de leche de las vacas en el tratamiento con ensilaje de caña de azúcar nueva, cuando se comparó con las del tratamiento con Merker cortada madura.

15. Las vacas en el tratamiento con ensilaje de caña de azúcar nueva, consumieron más materia seca (1.49 libras) por 100 libras de peso que las vacas en el tratamiento con yerba Merker cortada madura, las cuales consumieron 1.97 libras.

16. Los ensilajes de yerba Merker y los de caña cortada nueva son excelentes medios de proveer forraje à las vacas lecheras. Resultan aún más esenciales para la alimentación del ganado durante las temporadas de prolongadas sequías y también cuando es difícil poder conseguir buenas yerbas para corte.

LITERATURE CITED

1. U. S. D. A. Farmer's Bul. **32** 1903.
2. May, D. W., Dairying in Puerto Rico, Puerto Rico Agricultural Experiment Station, Mayaguez, P. R., Bul. **29** 12–13, 1922.
3. Rivera Brenes, L., Marchán, F., and Del Toro, E., Studies on silage in Puerto Rico I, Methods of ensiling and resulting quality of Merker, cane tops and Para grass silages, Jour. Agr. Univ. P. R. **31** (2) 168–79 1947.

INFLUENCE OF NITROGEN, CALCIUM, AND BORON ON THE NODULATION, YIELD, AND PROTEIN CONTENT OF TROPICAL KUDZU

George Samuels and Pablo Landrau, Jr.[1]

INTRODUCTION

Tropical kudzu (*Pueraria phaseoloides*) *javanica*, has become important in Puerto Rico as a valuable legume for livestock and the control of soil erosion. Unlike its northern relative, kudzu (*Pueraria thunbergiana*), which is widely planted in the southern United States, little is known about the response of tropical kudzu to lime and fertilizers.

Telford and Childers (4)[2] reported that tropical kudzu grew well on a Catalina clay, a lateritic soil with a pH 4.5, on Nipe clay, and on another lateritic soil of pH 4.6 to 5.1 with applications of a complete fertilizer such as 10-10-5 at the rate of about 400 to 600 pounds per acre. In a greenhouse experiment, Rodríguez (1) obtained significantly higher yields when kudzu was grown at a pH 7.5 as compared with pH 5.2. Landrau, Samuels, and Rodríguez (1) reported significantly higher yields of tropical kudzu on an acid Fajardo clay (pH 5.3) when it was limed to pH 6.5. Smith and Chandler (3) stated that soils of pH 5.5 were best for near maximum growth of kudzu.

In field observations the authors noted that tropical kudzu grown in plots which had recently received nitrogenous fertilizers did not possess as many nodules per plant as those grown in unfertilized or limed plots. Further observations over a period of 6 months revealed an increase in nodulation of the nitrogen-fertilized plants. In view of these observations and the reported good growth of tropical kudzu in acid soils (pH 5.5 and below), experiments were undertaken to determine the effects of lime, boron, and nitrogen on nodulation and yields of kudzu.

PROCEDURES

Tropical kudzu was grown in the greenhouse on Lares clay, an acid lateritic clay with a normal field pH of 4.4. The 0 to 8-inch surface horizon of the soil taken from a field cropped to kudzu was air-dried, screened through a ¼-inch mesh screen, and placed in 1-gallon enameled Mitscherlich pots. The soil in the pots was well mixed with appropriate fertilizers. The tropical kudzu seed were pretreated with a 1:1 sulfuric acid-water solution for one-

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[2] Numbers in parentheses refer to Literature Cited, p. 80.

TABLE 1.—*Yields of tropical kudzu, protein, and nodules, in response to different fertilizer treatments in greenhouse experiment 1*

No.	Treatment	Yield of tropical kudzu per pot		Mean nodules per plant	Mean protein content of kudzu, dry weight basis
		Green weight	Dry weight		
		Grams	*Grams*	*Number*	*Percent*
1	Control	28	6	59	15.1
2	Nitrogen	68	18	10	18.2
3	Lime	42	11	89	17.1
4	Lime and nitrogen	77	22	11	17.1
5	Lime and boron	63	17	5	16.9
6	General means	56	15	37	16.9
Least significant differences needed for comparison at the:					
5-percent level		12	3	32	6.7
1-percent level		17	4	45	9.4

TABLE 2.—*Yields of tropical kudzu in response to different fertilizer treatments in greenhouse experiment 2*

[Three cuttings]

No.	Treatments	Mean yield of tropical kudzu per pot on green and dry-weight basis							
		First cutting		Second cutting		Third cutting		Mean of 3 cuttings	
		Green weight	Dry weight	Green weight	Dry weight	Green weight	Dry weight	Green weight	Dry weight
		Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
1	Lime	65	15	132	28	82	23	93	22
2	Lime and boron	67	15	136	35	77	21	93	24
3	Boron	59	13	131	29	88	24	93	22
4	Nitrogen	81	18	140	37	84	23	102	26
5	Control	65	14	133	34	83	26	94	25
6	General means	67	15	134	33	83	23	95	24
Least significant difference needed for comparison at the:									
5-percent level		14	3	17	4	15	4	24	6
1-percent level		18	5	23	6	22	6	32	4

half hour and germinated in paper cups containing Lares soil from a field planted to kudzu. Three healthy plants were transplanted to each container.

The treatments used for the first experiment are given in table 1, and those for the second in table 2. All received P_2O_5 as 20-percent superphosphate and K_2O as 60-percent muriate of potash at the rate of 100 pounds each per acre. Calcium was applied as calcium carbonate, at the rate of 10,000 pounds per acre; nitrogen as ammonium sulfate, 250 pounds of N per acre; and boron as borax at 30 pounds per acre.

The kudzu for experiment 1 was harvested at a crop age of 3 months; in experiment 2 it was harvested in three cuttings made 4, 7, and 10 months after planting. Green and dry weights were made of the tops which were

TABLE 3.—*Number of nodules found on the tropical kudzu root system in greenhouse experiment 2, as affected by different fertilizer treatments*

[Three cuttings]

No.	Treatments	Mean number of nodules per plant for—			
		First cutting	Second cutting	Third cutting	Mean of 3 cuttings
1	Lime	151	208	230	196
2	Lime and boron	130	206	195	177
3	Boron	114	249	200	188
4	Nitrogen	22	187	233	147
5	Control	108	203	219	177
6	General means	105	211	215	177
Least significant difference needed for comparison at the:					
5-percent level		42	110	48	48
1-percent level		61	159	69	69

then analyzed for nitrogen. Protein was calculated as N × 6.25. The roots were carefully separated from the soil by washing and counts made of the number of nodules per plant for each treatment. In experiment 1 all treatments were replicated three times; in experiment 2, all treatments were replicated nine times for the first cutting, six times for the second, and three times for the last cutting, as three replications in each cutting were used for the nodule counts.

RESULTS

The results of the experiments are given in tables 1 to 5.

The use of nitrogen produced significant increases in yields of kudzu in both green and dry weight (tables 1 and 2). This increase was effective for the first cutting only, as there were no significant increases therefrom in the second or third cuttings, experiment 2, table 2. Lime produced significant

yield increases in experiment 1 only, there having been no appreciable differences for experiment 2 in any of the three cuttings. The combination

TABLE 4.—*Yields of protein in tropical kudzu in greenhouse experiment 2, as affected by different fertilizer treatments*

[Three cuttings]

No.	Treatments	Mean yield of protein in tropical kudzu, dry-weight basis, for—			
		First cutting	Second cutting	Third cutting	Mean of 3 cuttings
		Percent	*Percent*	*Percent*	*Percent*
1	Lime	14.9	18.5	21.4	18.27
2	Lime and boron	16.5	18.5	21.1	18.70
3	Boron	16.5	17.9	19.4	17.93
4	Nitrogen	14.4	18.0	19.8	17.40
5	Control	15.9	18.8	19.4	18.03
6	General means	15.6	18.3	20.2	18.1
Least significant difference needed for comparison at the:					
5-percent level		1.4	1.4	2.0	1.2
1-percent level		1.9	1.9	2.9	1.8

TABLE 5.—*Variation of soil pH in which tropical kudzu was grown in greenhouse experiment 2, as affected by different fertilizer treatments*

[Three cuttings]

No.	Treatments	Mean soil pH after harvesting—			
		First cutting	Second cutting	Third cutting	Mean of 3 cuttings
1	Lime	5.6	5.7	5.6	5.6
2	Lime and boron	5.6	5.7	6.0	5.8
3	Boron	5.2	5.2	5.1	5.2
4	Nitrogen	5.0	4.8	4.9	4.9
5	Control	5.2	5.1	5.1	5.1
Least significant difference needed for comparison at the:					
5-percent level		0.7	0.3	0.4	0.2
1-percent level		1.0	.4	.6	.3

of lime and nitrogen used in experiment 1 did not produce significantly higher yields than did the use of nitrogen alone.

The use of boron in combination with lime in experiment 1 significantly

increased yields over lime used alone. This increase was not realized in experiment 2 (table 2).

Determination of the nodulation counts per plant revealed some very interesting facts. In experiment 1, where nitrogen had been responsible for yield increases, it also produced a significant decrease in nodules per plant. The control had 59 nodules per plant and the nitrogen-fertilized kudzu only 10 (table 1). In the first cutting of experiment 2 the addition of nitrogen reduced the nodules per plant from 108 to 22 (table 3); this difference was not significant for the second cutting made 7 months after the nitrogen had been applied. This also held true for the third cutting.

The application of lime increased nodulation over the control in the first cutting in both experiments, the difference being just barely significant at the 5-percent level in experiment 2 and just short of it in experiment 1. In the second and third cuttings of experiment 2, the number of nodules per plant was about the same for the lime and control treatments (table 3). The use of boron with lime gave a significant reduction in nodules per plant in the first experiment, but this was not true for the second experiment wherein neither boron nor boron plus lime produced significant differences in nodule counts.

The use of lime and nitrogen in experiment 1 (table 1) reduced nodules per plant as did nitrogen used alone. Lime in the presence of the nitrogen did not increase the nodulation of the kudzu.

The protein content of the kudzu was highest in experiment 1, where nitrogen was used alone; however, the increase was not significant (table 1). In experiment 2 also, none of the treatments caused significant increases in protein, except for lime in the third cutting; here the increase was just significant at the 5-percent level.

The pH values of the soil taken after the first cutting in experiment 2 (table 5) showed no significant differences. After the second cutting, the soil under nitrogen treatment with ammonium sulfate decreased in pH. The pH of the limed soils also increased significantly over the control, as was likewise true for the third cutting. The pH of the control, 5.1, was somewhat higher than the pH 4.4 of the Lares clay used in experiment 1. The higher pH of the control in experiment 2 coupled with lack of pH differences for the soil at the first cutting when limed, may help to explain the failure to obtain significant yield increases in kudzu in experiment 1.

DISCUSSION

The effect of nitrogen on tropical kudzu yields and nodulation is of great interest. The yields of kudzu were increased by the addition of nitrogen fertilizer to the soil in the first cutting in both experiments, but the nodulation of the kudzu was drastically reduced. The reduction in nodulation is

in keeping with the findings of previous workers (2, 5) who have shown that the addition of nitrogen to the soil interferes with the fixation of free nitrogen by inoculated legumes, and reduces the number of nodules per plant.

The increased yields of kudzu attributable to the application of nitrogen to the soil were significant for the cutting immediately following the application (the first cutting in both experiments). This indicates that the nitrogen needs of kudzu, even when well-nodulated, were not satisfactorily supplied by the nitrogen fixed through the nodule mechanism. It seems, therefore, that under field conditions, new stands of tropical kudzu can effectively use more nitrogen than is provided by fixation.

The results of the greenhouse experiments carried out, as well as of field experiments (1), indicates that the use of nitrogen influences yields beneficially for the first cutting of new plantings, despite any adverse effect on nodulation; and that by the time of the second cutting (3 months after the first) the nitrogen-treated plants have the same number of nodules per plant as the untreated or limed plants. Tropical kudzu also showed a marked ability to grow well at a soil pH near 5 and to produce large numbers of nodules per plant as compared with its growth in limed soils. The number of nodules per plant was higher for the control on experiment 2, with a mean soil pH of 5.1, than in control of experiment 1 where the soil pH was 4.4.

SUMMARY

The use of nitrogen, calcium, and boron as soil treatments influenced tropical kudzu nodulation and yields as follows:

1. Applications of nitrogen reduced nodulation per plant drastically, but increased yields significantly in the first cutting.

2. Lime increased nodulation and yields somewhat, if applied to soil the pH of which was 4.4, but when the soil pH was 5.1, the increase was barely significant.

3. When used with lime, nitrogen reduced nodulation as much as it did when used alone.

4. Boron or boron with lime had no consistent influence on yields or nodulation.

5. The protein content of the kudzu was not measurably influenced by any of the treatments as compared with the control.

RESUMEN

El uso de los elementos nitrógeno, calcio y boro influyó sobre la formación de nódulos y sobre el rendimiento del kudzu, como sigue:

1. Las aplicaciones de nitrógeno redujeron drásticamente la formación de nódulos, pero aumentaron significativamente los rendimientos del primer corte.

2. Cuando se aplicó cal al terreno, ésta aumentó el número de nódulos por planta. Se observó un pequeño aumento en los rendimientos cuando el suelo registraba un pH de 4.4. En los suelos con un pH de 5.1 no se pudo apreciar aumento significativo alguno.

3. Las aplicaciones conjuntas de nitrógeno y cal redujeron la formación de nódulos al nivel del tratamiento con nitrógeno solo; a pesar de la presencia de la cal.

4. El boro solo o el boro aplicado conjuntamente con la cal, no influyeron consistentemente sobre la formación de nódulos o sobre los rendimientos.

5. Ninguno de los tratamientos al compararse con el tratamiento testigo influyó, en forma que pudiera medirse, sobre el contenido de proteína en el kudzu.

LITERATURE CITED

1. Landrau, P., Samuels, G., and Rodríguez, P., The influence of fertilizers, minor elements, and soil ph on the growth of tropical kudzu, *J. Agr. Univ. P. R.* **37** (1) pp. 81–85, 1953.
2. Normand, A. G., *Soil Sci. Soc. Amer. Proc.* (1943) **8** 226 1944.
3. Smith, R. M. and Chandler, J. V., Tropical kudzu moves into Puerto Rico, *Crops and Soils*, pp. 12–14, March 1951.
4. Telford, E. A., and Childers, N. F., Federal Expt. Station in Puerto Rico, U.S.D.A. Office of Expt. Sta., Cir. No. **67**, 1947.
5. Thornton, G. D., *Soil Sci. Soc. Amer. Proc.* (1946) **11** 249 1947.

INFLUENCE OF FERTILIZERS, MINOR ELEMENTS, AND SOIL pH ON THE GROWTH AND PROTEIN CONTENT OF TROPICAL KUDZU

P. Landrau, Jr., G. Samuels, and P. Rodríguez[1]

INTRODUCTION

There has been a long-time need for a vigorous legume in Puerto Rico, capable of being used for soil-erosion control and as a pasture and hay crop. One of the first projects of the Agricultural Experiment Station[2] was the establishment of field experiments to study new legumes suitable for use in Puerto Rico. From this beginning the Station has been concerned with the task of finding suitable legumes for the farmers.

Many legumes have been tested, both native and imported. One of these, alfalfa (*Medicago sativa*), showed promise of providing a high-tonnage, high-protein legume for Puerto Rico. However, it proved susceptible to certain insect injury and its best growth was limited to those soils of pH above 6.5. The majority of these neutral to alkaline soils are found in the irrigated areas of the northwest and southern portions of the Island where there is insufficient rainfall to support the growth of this legume. The humid sections of the Island where the soil pH is normally below 5.5, still lacks a high-protein legume comparable to alfalfa.

Kudzu (*Pueraria thunbergiana* Benth.), which has done so well in the humid southeastern United States, has failed to grow satisfactorily under tropical conditions. With the introduction of tropical kudzu (*Pueraria phaseoloides* (javanica) Benth.), it appears that a legume suitable for the humid areas of Puerto Rico has been found.

Since its introduction in 1940, by the Soil Conservation Service, many conflicting observations have been reported concerning the growth habits, agronomic needs, pH tolerance, nutritional and soil requirements of tropical kudzu. Smith and Chandler (4)[3] reported that, on fertile land, a pH of 5.5 permitted near-maximum growth, and that phosphorus was the soil nutrient most likely to be deficient. However, the data presented showed that highest yields were made when phosphate was used with lime; and insufficient data were presented to tell whether the increase was attributable to the phosphate, or the lime, or a combination of both. Telford and Childers

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[2] Then called the Sugar Cane Experiment Station, 1912.

[3] Numbers in parentheses refer to Literature Cited, p. 95.

(5) used a 10-10-5 complete fertilizer to establish kudzu in their field work. Samuels and Landrau (3), in greenhouse experiments, found that lime and nitrogen applications did increase kudzu yields.

In order to obtain a clear picture of the fertilizer requirements and pH demands of tropical kudzu, the Agronomy and Horticulture Department of the Agricultural Experiment Station initiated a study of the problem. This paper reports the findings of the work.

PROCEDURES

Greenhouse pH Experiment

The first investigation of the pH requirements of kudzu consisted of a greenhouse pot experiment. Using a Río Piedras clay with a natural pH of 5.2, pH levels of 5.2, 5.5, 6.0, 6.5, 7.0, and 7.5 were established, each level being replicated nine times. The soils were brought to the required pH levels by mixing in the proper quantity of $CaCO_3$ as determined by the method of Riera (2). The soils were placed in 1-gallon Mitscherlich pots, innoculated, and then planted with kudzu, using three plants per pot. The tops were harvested six months after planting.

Ceiba Field Experiment

A fertilizer experiment using different levels of nitrogen, phosphorus, and potassium was conducted at the "Ceiba" field of the Agricultural Experiment Station at Río Piedras. The soil type used was classified as a Río Piedras clay, an acid plastic clay derived from shale (1). The crop was planted April 10, 1947, on 1/100-acre plots using seven replications per treatment. The treatments used are given later in table 2. The experiment was harvested on October 15, 1947, at an age of 6 months.

García-Méndez Field Experiment

A fertilizer-lime experiment was carried out at the García-Méndez farm at Río Piedras on a Fajardo clay, a reddish-brown friable acid clay derived from old-hill alluvial material and hill-shale outwash (1). The treatments used consisted of zero, medium, and high levels of nitrogen, phosphorus, and potassium, as well as a no-fertilizer check (see table 3). Each treatment was replicated six times at a pH level of 5.3 (original soil pH) and one of 6.5 (limed soil). Applications of 14,000 pounds of 93-percent $CaCO_3$ per acre were used to obtain a soil pH of 6.5; this rate was determined by the method of Riera (2). All plots were limed and fertilized at planting only.

The experimental triple-lattice design was laid out on land with a 30-percent slope. There were 16 treatments and six replications. The plot size was 20 by 21½ feet or one one-hundredth of an acre. Each plot was

separated from its neighbor by 3-foot lanes to prevent the long vines of the kudzu from entangling.

Acid-scarified kudzu seeds were planted in paper cups in the greenhouse. After 3 weeks, the kudzu was transplanted to the field, cup and all. The spacing used in the plots was 3 feet within rows. The planting was made February 3, 1949, and the cuttings were made on July 29, 1949, November 25, 1949, and August 8, 1950. At time of cutting 500-gm. composite samples from each plot were taken and oven-dried (70°C.), to be used for the estimation of dry weights and protein analyses.

Corozal Field Experiment

In the Corozal field experiment not only various levels of lime and fertilizer, but also of minor element treatments were utilized. The experiment

TABLE 1.—*Yields of kudzu in the greenhouse experiment, as influenced by soil pH*

Treatment No.	Soil pH	Yield of kudzu in dry weight per pot
		Grams
1	5.2	81.1
2	5.5	88.9
3	6.0	84.3
4	6.5	90.1
5	7.0	96.7
6	7.5	101.8
Least significant difference needed for comparison at the:		
5-percent level		6.4
1-percent level		8.6

was made on a Lares clay at the Corozal Substation of the Agricultural Experiment Station. The soil is an acid lateritic clay derived from washed materials of the acid red soils situated in the hills above the very old high-drained terraces where the Lares clay is found (1). The treatments used and their rates of application are given later in table 7.

The experimental design was a triple lattice with 16 treatments and six replications laid out on land with a slope ranging from 15 to 30 percent. The plot size was one one-hundredeighty-second of an acre. The lime was applied broadcast and worked into the upper 6 inches of soil 1 month before planting. The kudzu was germinated in paper cups, containing innoculated soil from the experimental areas, and then transplanted, cups and all, when 3 weeks old. The plants were set out April 5, 1950 and cuttings were made November 6, 1950, June 19, 1951, and September 25,

1951. Samples were taken at each cutting for estimation of dry weights (oven-dried at 70°C.) and protein analyses.

RESULTS

Greenhouse pH Experiment

The yields of kudzu obtained in the greenhouse experiment are given in table 1 in grams per pot. The data show that, with the exception of pH 6.0, the yields of kudzu increased with increased pH. The highest pH level, 7.5, gave a 25-percent higher yield than the lowest, 5.2. The results of this experiment indicate that, at least under greenhouse conditions, tropical

TABLE 2.—*Yields of tropical kudzu forage harvested at the Ceiba field experiment, as affected by various fertilizer treatments*

Treatment No.	Pounds per acre of—			Mean yield of kudzu forage, green weight per acre
	N	P_2O_5	K_2O	
				Tons
1	0	0	0	0.62
2	0	200	200	1.39
3	83	200	200	2.95
4	165	0	200	2.66
5	165	100	200	4.27
6	165	200	0	4.48
7	165	200	100	5.05
8	165	200	200	3.89
Mean of treatments				3.14
Least significant difference needed for comparisons at the:				
1-percent level				1.68
5-percent level				1.26

kudzu, like alfalfa and certain clovers, responds to liming and prefers soils near a neutral pH (7.0) for optimum growth.

Ceiba Field Experiment

The yields of kudzu obtained in the Ceiba field experiment are presented in table 2 in green weights per acre. The use of nitrogen in combination with phosphorus and potassium gave significant yield increases. The use of 83 pounds of nitrogen per acre gave a yield increase of 1.56 tons of green kudzu forage over the no-nitrogen treatment (treatment 3 minus treatment 2). The use of 165 pounds of nitrogen also produced increases, but these were not significant over the first increment of 83 pounds of nitrogen (treatments 8 minus treatment 3). Nitrogen acting alone was responsible

for the majority of the yield increases. If we compare treatment 2, where 200 pounds each of phosphorus and potassium were used with no nitrogen, with the unfertilized control (treatment 1), we see that the use of these two fertilizer elements alone did not give significant yield increases. When nitrogen was added, the increase in yield became significant.

The use of 100 pounds of P_2O_5 (treatment 5) gave a significant yield increase over the no-phosphorus treatment (treatment 4). The potassium treatments failed to produce a significant response. The use of nitrogen in

TABLE 3.—*Yields from 3 cuttings of tropical kudzu forage (green weight), García Méndez experiment, as affected by various fertilizer treatments and soil pH*

Treatment No.	Pounds per acre of—			Mean yields of tropical kudzu forage harvested, green weight per acre									
				First cutting		Second cutting		Third cutting		Total of 3 cuttings		Mean of 3 cuttings	
	N	P_2O_5	K_2O	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5
				Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	0	0	0	3.75	7.39	5.29	4.58	7.05	7.41	16.09	19.38	5.36	6.46
2	0	200	200	5.29	7.75	5.29	4.42	6.73	7.41	17.31	19.58	5.77	6.53
3	83	200	200	8.43	9.51	5.13	5.13	7.60	8.71	21.16	23.35	7.05	7.78
4	165	0	200	7.23	8.23	5.20	5.73	8.58	7.35	21.01	21.31	7.00	7.10
5	165	100	200	7.93	9.08	5.01	5.28	8.19	6.66	21.13	21.02	7.04	7.01
6	165	200	0	8.96	9.26	5.61	5.41	6.93	7.12	21.50	21.79	7.17	7.26
7	165	200	100	9.60	9.58	5.14	4.38	7.79	8.15	22.53	22.11	7.51	7.37
8	165	200	200	8.11	9.13	5.40	5.78	7.24	8.90	20.75	23.81	6.92	7.94
Mean of treatments				7.41	8.74	5.26	5.09	7.51	7.71	20.19	21.54	6.73	7.18
Least significant difference needed for comparison at the:													
5-percent level				2.02		1.11		1.27		2.55		0.85	
1-percent level				2.70		1.44		1.68		3.37		1.13	

combination with phosphorus appears to be the required fertilizer combination for optimum yields of tropical kudzu on the Río Piedras clay in the area of the experiment. There were no further cuttings.

García-Méndez Field Experiment

GREEN WEIGHT

The yields of tropical kudzu obtained in the García-Méndez Field experiment are given in table 3. In the first cutting the limed soils produced significantly higher yields than the unlimed in the no-fertilizer and no-nitrogen treatments (treatments 1 and 2). The use of lime produced 3.64 tons more green forage than the unlimed treatment (treatment 1) in the

unfertilized check. Liming with the addition of fertilizers produced no significant yield increases when no nitrogen was added (treatment 2). In the other treatments (treatments 3 to 8) where complete fertilizers were applied, there were no significant differences between the unlimed and limed plots.

In the first cutting, the use of 83 pounds of nitrogen gave significantly higher yields than did the no-nitrogen treatment (treatment 3 minus treatment 2) for the unlimed soils. With lime added, the use of nitrogen did not significantly raise yields. No appreciable yield increases could be attributed to the use of either phosphorus or potassium on the limed or unlimed plots.

The second and third cuttings of this experiment revealed no significant differences attributable either to liming or to fertilizers.

The total of three cuttings averaged more than 20 tons of green forage in one year for the entire experiment. With no fertilizer (treatment 1), the use of lime produced significant yield increases; however, these were made mostly in the first cutting. From this experiment it appears that the use of lime benefited only the first cutting, and did not produce a long-range effect. This advantage gained by liming in the first cutting disappeared with time, and the second and third cuttings showed no response to it.

Nitrogen also proved of value in starting the kudzu. Although we normally think of a legume as being an effective producer of its own nitrogen requirements, it appears that it can use a nitrogen-fertilizer boost to help establish itself on the heavy plastic Fajardo clay.

DRY WEIGHT

The yields of kudzu in dry weight of forage per acre are given in table 4. The same trends and significance discussed under green weight appear here. The total mean yield of dry forage (oven-dried at 70°C.) for three cuttings was over 4 tons per acre.

PROTEIN

Kudzu not only produces a good tonnage of forage for a legume crop; it also produces a high-protein forage. The protein in the kudzu on a dry-weight basis ranged from 15 to 25 percent in the experiment, as can be seen in table 5. The mean protein produced was 19.7 and 20.5 percent on a dry-weight basis for the unlimed and limed treatments, respectively.

The first cutting showed increases in protein from liming, for the unfertilized plots and those receiving no nitrogen (treatments 1 and 2). When nitrogen, phosphorus, and potassium were used (treatments 3 to 8) no appreciable response was obtained from the use of lime. The use of 83 pounds of nitrogen per acre increased the protein in the kudzu from the unlimed plots only; when lime was used, nitrogen did not increase the protein

TABLE 4.—*Yields from 3 cuttings of tropical kudzu forage (dry weight), García Méndez experiment, as affected by various fertilizer treatments and soil pH*

Treatment No.	Pounds per acre of—			Mean yields of tropical kudzu forage harvested, dry weight per acre									
				First cutting		Second cutting		Third cutting		Total of 3 cuttings		Mean of 3 cuttings	
	N	P_2O_5	K_2O	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5
				Tons	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	0	0	0	0.75	1.32	0.92	0.84	1.84	1.88	3.51	4.04	1.17	1.35
2	0	200	200	1.01	1.32	.94	.72	1.95	1.94	3.90	3.98	1.30	1.33
3	83	200	200	1.50	1.62	.86	.84	1.84	2.09	4.20	4.55	1.40	1.52
4	165	0	200	1.30	1.41	.89	.95	1.79	2.07	3.98	4.43	1.33	1.48
5	165	100	200	1.28	1.62	.88	.88	1.90	2.12	4.06	4.62	1.35	1.54
6	165	200	0	1.50	1.64	1.04	.94	1.84	1.86	4.38	4.44	1.46	1.48
7	165	200	100	1.59	1.65	.83	.72	1.85	1.93	4.27	4.30	1.42	1.43
8	165	200	200	1.49	1.69	.97	1.07	1.95	2.15	4.41	4.91	1.47	1.44
Mean of treatments				1.30	1.53	0.92	0.87	1.87	2.01	4.09	4.41	1.36	1.45
5-percent level				0.36		0.20		0.31		0.47		0.16	
1-percent level				.48		.26		.41		.62		.21	

TABLE 5.—*Protein in 3 cuttings of tropical kudzu forage, García Méndez experiment, as affected by various fertilizer treatments and soil pH*

Treatment No.	Pounds per acre of—			Mean protein content of tropical kudzu harvested, dry weight							
				First cutting		Second cutting		Third cutting		Mean of 3 cuttings	
	N	P_2O_5	K_2O	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5
				Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
1	0	0	0	15.3	17.8	16.2	17.7	22.8	23.7	18.1	19.7
2	0	200	200	16.8	19.2	17.4	17.8	22.1	25.0	18.8	20.7
3	83	200	200	18.6	18.9	18.7	17.8	22.9	23.4	20.1	20.0
4	165	0	200	18.4	19.4	18.2	19.1	21.1	22.1	19.2	20.2
5	165	100	200	18.7	18.8	18.8	19.0	22.5	24.0	20.0	20.0
6	165	200	0	18.7	18.5	18.3	18.7	24.1	24.5	20.4	20.6
7	165	200	100	18.6	20.1	19.5	20.3	23.7	23.9	20.6	21.4
8	165	200	200	18.8	20.2	18.5	18.4	23.6	22.6	20.3	20.4
Means of treatments				18.0	19.1	18.2	18.6	22.9	23.7	19.7	20.5
Least significant difference needed for comparison at the:											
5-percent level					1.8		1.7		1.9		
1-percent level					2.4		2.3		2.6		

content (treatment 3 minus treatment 2). As found for yields of forage (tables 3 and 4) the use of nitrogen on kudzu was more effective on the unlimed than on the limed soils. The application of phosphorus or potassium fertilizers had no measurable influence on protein yields.

The second cutting showed no appreciable differences in protein content when lime was used; nor did nitrogen, phosphorus, or potassium fertilizers increase protein yields.

TABLE 6.—*Yields of protein harvested in 3 cuttings of tropical kudzu, García Méndez experiment, as affected by various fertilizer treatments and soil pH*

Treatment No.	Pounds per acre of—			Mean yields of protein harvested from tropical kudzu, dry weight per acre									
				First cutting		Second cutting		Third cutting		Total of 3 cuttings		Mean of 3 cuttings	
	N	P_2O_5	K_2O_5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5	Unlimed pH 5.3	Limed pH 6.5
				Pounds	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	0	0	0	229	470	298	297	839	891	1,366	1,658	455	553
2	0	200	200	339	507	327	256	862	970	1,528	1,733	509	577
3	83	200	200	558	612	322	299	843	978	1,723	1,889	574	630
4	165	0	200	478	547	324	363	755	915	1,557	1,825	519	608
5	165	100	200	479	609	331	334	855	1018	1,665	1,961	555	654
6	165	200	0	561	607	380	352	887	911	1,828	1,870	609	623
7	165	200	100	591	663	324	292	877	922	1,792	1,877	597	626
8	165	200	200	560	683	359	394	920	972	1,839	2,049	613	683
Means of treatments				474	587	333	323	855	947	1,662	1,858	554	619
Least significant difference needed for comparison at the:													
1-percent level				176		107		203		262		87	
5-percent level				133		81		153		198		66	

In the third cutting there was an increase in protein content when lime was applied in the no-nitrogen treatment (treatment 2). However, this was the only significant response to liming. The use of nitrogen, phosphorus, or potassium fertilizers did not appreciably increase the protein content of the kudzu.

Most of the protein concentrate for animal feeds is imported into Puerto Rico. It is therefore of interest to see how large a yield of protein in pounds per acre (dry-weight basis) was produced. The results obtained are given in table 6. The total of three cuttings produced a mean yield of over 1,700 pounds of protein per acre. It would require 8.5 tons, or 305 bushels[4], of

[4] One bushel of shelled corn equal to 56 pounds.

corn to produce the same quantity. There is no doubt about the saving in money and shipping space tropical kudzu grown locally can mean to the people of Puerto Rico.

TABLE 7.—*Yields from 3 cuttings of tropical kudzu forage (green weight), Corozal experiment, as affected by various fertilizer treatments, including minor elements, and soil pH*

Treatment No.	Pounds per acre of—			Lime used per acre	Soil pH	Mean yields of tropical kudzu forage, green weight per acre				
	N	P_2O_5	K_2O			First cutting	Second cutting	Third cutting	Total of 3 cuttings	Mean of 3 cuttings
				Pounds		*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	0	0	0	7,500	6.0	6.95	3.91	4.46	15.32	5.11
2	0	200	200	7,500	6.0	5.44	4.91	3.82	14.18	4.73
3	83	200	200	7,500	6.0	6.57	5.10	4.57	16.23	5.41
4	165	0	200	7,500	6.0	6.68	4.55	3.44	14.67	4.90
5	165	100	200	7,500	6.0	6.10	4.28	3.53	13.90	4.64
6	165	200	0	7,500	6.0	6.33	4.28	3.68	14.29	4.77
7	165	200	100	7,500	6.0	6.00	4.46	3.79	14.31	4.77
8	165	200	200	7,500	6.0	5.97	3.91	3.80	13.69	4.57
9	0	0	0	0	4.5	6.59	3.46	3.55	13.60	4.53
10	83	200	200	3,500	5.0	6.10	4.19	4.00	14.29	4.77
11	83	200	200	12,500	7.0	5.97	5.10	4.46	15.52	5.17
12[1]	83	200	200	0	4.5	5.95	2.55	3.75	12.25	4.08
13[1]	83	200	200	7,500	6.0	5.70	4.10	3.62	13.41	4.48
14[1]	83	200	200	12,500	7.0	6.64	5.10	4.53	16.27	5.42
15[2]	83	200	200	0	4.5	5.73	4.28	3.89	13.90	4.64
16[2]	83	200	200	7,500	6.0	6.52	4.10	4.50	15.11	5.04
Mean of all treatments						6.21	4.26	3.97	14.43	4.82
Least significant difference needed for comparisons at the:										
1-percent level						1.64	1.71	1.26	2.73	.91
5-percent level						1.24	1.29	.95	2.02	.67

[1] Plus 50 pounds of borax.

[2] Plus 300 pounds of magnesium oxide.

Corozal Field Experiment

GREEN WEIGHT

The yields of forage obtained in the Corozal field experiment are given in table 7 in green weight. In the first cutting applications of lime up to 12,500 pounds per acre failed to produce significant yield increases (treatments 1, 3, 10, and 11) as compared with yields from unlimed soil (treatment 9). The use of nitrogen, phosphorus, or potassium fertilizer did not give any significant increases in yields. Minor-element fertilizers, magne-

sium oxide and borax, used at various pH levels did not measurably increase yields (treatments 12 to 16).

The first cutting of this experiment did not respond to liming and nitrogen as did that in the García-Méndez experiment. The normal soil pH encountered here was about 4.5, which was lower than the 5.3 of the Fajardo clay at García-Méndez. Soil samples taken after the first cutting revealed that the unlimed plots had a mean pH of 5.4, and there was evidence of washing of lime from limed to unlimed plots. It was probable that the heavy rains at the beginning of the experiment, before sufficient ground cover was established by the kudzu, washed some of the lime from the limed to the unlimed plots.

TABLE 8.—*Yields from 3 cuttings of tropical kudzu forage (dry weight) Corozal experiment, as affected by various fertilizer treatments, including minor elements, and by soil pH*

Treatment No.	Pounds per acre of—			Lime used per acre	Soil pH	Mean yield of tropical kudzu forage dry weight per acre				
	N	P_2O_5	K_2O			First cutting	Second cutting	Third cutting	Total of 3 cuttings	Mean of 3 cuttings
				Pounds		*Tons*	*Tons*	*Tons*	*Tons*	*Tons*
1	0	0	0	7,500	6.0	1.80	1.13	0.84	3.77	1.26
2	0	200	200	7,500	6.0	1.36	1.33	.75	3.44	1.15
3	83	200	200	7,500	6.0	1.64	1.49	.86	3.99	2.48
4	165	0	200	7,500	6.0	1.75	1.40	.71	3.86	1.29
5	165	100	200	7,500	6.0	1.58	1.31	.84	3.73	1.24
6	165	200	0	7,500	6.0	1.73	1.27	.73	3.73	1.24
7	165	200	100	7,500	6.0	1.47	1.29	.76	3.53	1.18
8	165	200	200	7,500	6.0	1.58	1.16	.66	3.40	1.13
9	0	0	0	0	4.5	1.69	.98	.71	3.39	1.13
10	83	200	200	3,500	5.0	1.55	1.26	.62	3.42	1.15
11	83	200	200	12,500	7.0	1.58	1.49	.86	3.93	1.31
12[1]	83	200	200	0	4.5	1.44	.82	.75	3.00	1.00
13[1]	83	200	200	7,500	6.0	1.58	1.27	.64	3.49	1.16
14[1]	83	200	200	12,500	7.0	1.49	1.49	.82	3.80	1.27
15[2]	83	200	200	0	4.5	1.77	1.16	.76	3.69	1.24
16[2]	83	200	200	7,500	6.0	1.36	1.11	.84	3.31	1.11
Mean of treatments						1.58	1.26	.76	3.59	1.20
Least significant differences needed for comparison at the:										
5-percent level						0.36	0.42	0.20		
1-percent level						.49	.55	.27		

[1] Plus 50 pounds of borax.

[2] Plus 300 pounds of magnesium oxide.

The second and third cuttings gave no indications of yield increases that could be attributed to any of the treatments used.

It appears that in the more friable and better drained soils of the Lares clay, as compared with the plastic, poorly drained Fajardo clay, the kudzu

TABLE 9.—*Protein in 3 cuttings of tropical kudzu forage, Corozal experiment, as affected by various fertilizer treatments, including minor elements, and by soil pH*

Treatment No.	Pounds per acre of—			Lime used per acre	Soil pH	Mean protein content of tropical kudzu, dry weight			
	N	P_2O_5	K_2O			First cutting	Second cutting	Third cutting	Mean of 3 cuttings
				Pounds		*Percent*	*Percent*	*Percent*	*Percent*
1	0	0	0	7,500	6.0	18.9	17.1	18.6	18.2
2	0	200	200	7,500	6.0	18.2	15.0	17.9	17.0
3	83	200	200	7,500	6.0	19.8	16.4	18.0	18.1
4	165	0	200	7,500	6.0	19.0	16.9	18.0	18.0
5	165	100	200	7,500	6.0	19.3	14.6	18.2	17.4
6	165	200	0	7,500	6.0	21.2	16.8	19.3	19.1
7	165	200	100	7,500	6.0	20.2	16.8	18.1	18.4
8	165	200	200	7,500	6.0	19.0	18.4	19.4	18.9
9	0	0	0	0	4.5	18.0	12.6	16.2	15.6
10	83	200	200	3,500	5.0	20.0	16.4	17.8	18.1
11	83	200	200	12,500	7.0	19.6	18.0	18.0	18.5
12[1]	83	200	200	0	4.5	18.1	13.9	15.7	15.9
13[1]	83	200	200	7,500	6.0	20.8	17.3	17.6	18.6
14[1]	83	200	200	12,500	7.0	19.9	15.7	17.5	17.7
15[2]	83	200	200	0	4.5	18.9	14.8	17.4	17.0
16[2]	83	200	200	7,500	6.0	19.03	16.0	17.3	17.4
Mean of treatments						19.37	16.04	17.81	17.74
Least significant difference needed for comparison at the:									
5-percent level						2.5	2.2	1.80	1.34
1-percent level						3.3	2.9	2.39	1.78

[1] Plus 50 pounds of borax.

[2] Plus 300 pounds of magnesium oxide.

was able to establish itself fast enough to make the use of lime or fertilizers of negligible value.

DRY WEIGHT

The yields of kudzu forage on a dry-weight basis are given in table 8. The trends are similar to those discussed under green weight. In general, there was no appreciable response for the three cuttings to either lime, major-element, or minor-element fertilizers.

PROTEIN

The protein content of the kudzu harvested at Corozal is given in table 9. In the first cutting lime used alone failed to produce significant increases in protein content. The combination of lime and complete fertilizer with or without minor elements also failed to give consistent significant increases in protein content of the kudzu.

TABLE 10.—*Yields of protein harvested in 3 cuttings of tropical kudzu, Corozal experiment, as affected by various fertilizer treatments, including minor elements, and by soil pH*

Treatment No.	Pounds per acre of—			Lime used per acre	Soil pH	Mean yield of protein harvested from tropical kudzu, dry weight per acre				
	N	P_2O_5	K_2O			First cutting	Second cutting	Third cutting	Total of 3 cuttings	Mean of 3 cuttings
				Pounds		*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
1	0	0	0	7,500	6.0	680	390	310	1,380	460
2	0	200	200	7,500	6.0	500	400	270	1,170	390
3	83	200	200	7,500	6.0	650	490	310	1,450	483
4	165	0	200	7,500	6.0	660	470	260	1,390	463
5	165	100	200	7,500	6.0	610	380	310	1,300	433
6	165	200	0	7,500	6.0	730	430	280	1,440	480
7	165	200	100	7,500	6.0	590	430	280	1,300	433
8	165	200	200	7,500	6.0	600	430	260	1,290	430
9	0	0	0	0	4.5	610	250	230	1,090	363
10	83	200	200	3,500	5.0	620	410	220	1,250	417
11	83	200	200	12,500	7.0	620	540	310	1,470	490
12[1]	83	200	200	0	4.5	520	230	240	990	330
13[1]	83	200	200	7,500	6.0	660	440	230	1,330	443
14[1]	83	200	200	12,500	7.0	590	470	290	1,350	450
15[2]	83	200	200	0	4.5	670	340	260	1,270	423
16[2]	83	200	200	7,500	6.0	520	360	290	1,170	390
Mean of treatments						614	404	272	1,290	430

[1] Plus 50 pounds of borax.

[2] Plus 300 pounds of magnesium oxide.

The use of lime produced significant increases in protein for the second and third cuttings when no fertilizer was used (compare treatments 1 and 9). The use of nitrogen, phosphorus, or potassium fertilizers failed to show consistent increases in the protein content. The application of borax in combination with fertilizer and lime did not produce consistent increases in the protein content of the kudzu. The same was true for magnesium oxide (treatments 15 and 16).

The mean of the three cuttings revealed that lime when used alone gave

significant increases in the protein content of the kudzu, but these increases were encountered in the second and third cuttings only. This result is just the reverse of the findings in the García-Méndez experiment where liming was effective in the first cutting only. At Corozal it appears that lime had its normal long-range effect and it produced beneficial results in the later cuttings. At present no explanation can be offered of this reversal in the behavior of the lime on kudzu.

The pounds of protein produced per acre are given in table 10. The results are similar to those discussed for the percentage of protein in table 9. The mean yields indicate that the total weight of protein produced was somewhat higher for the García-Méndez experiment. The Corozal experiment gave larger yields in the first cutting which decreased with the number of cuttings. At García-Méndez, the third cuttings gave higher yields than did the other two.

DISCUSSION

The usual recommendation for growing legumes is to use soils near neutral (pH 7) and to lime acid soils. No nitrogen is usually recommended, as the legume is assumed to be an efficient producer of its own nitrogen. It appears from the results of these field experiments, that nitrogen can be of value in establishing a stand of kudzu. The nitrogen fertilizer increases both yield and protein content of the plant. The beneficial effect of nitrogen applications is quickly realized in the cutting to which it is applied, but the gains are not so evident in subsequent cuttings. Observations made by the authors on field plots have shown a marked reduction in nodulation when nitrogen fertilizers had been recently applied to the soil for new plantings. Six months after the application of the nitrogen, the plots showed an increase in nodulation.

Tropical kudzu has displayed an ability to grow well at pH's in the range of 4.5 to 5.5. However, the use of lime stimulated yields in both greenhouse and field experiments. In the García-Méndez experiment, the yield increase from liming was realized on the heavy, plastic Fajardo clay in the first cutting only, whereas, in the Corozal experiment, there was a significant increase in protein from liming in only the second and third cuttings, and no increase at all in yields of forage that could be attributed to liming.

In all the experiments, except for the one in Ceiba, the use of phosphorus fertilizers produced neither yield nor protein increases. Potassium fertilizers had no significant influence on the yields of kudzu in the experiments discussed. However, evidences of potassium deficiencies have been noted by the authors on kudzu growing in sandy soils such as the Cataño loamy sand.

SUMMARY

The effect of fertilizers and lime on the yield and protein production of tropical kudzu, as observed in the experiments here reported, is as follows:

1. In a greenhouse experiment, kudzu yields increased with increased pH on limed soils, with the highest yield at pH 7.5.

2. Nitrogen and phosphorus produced significant increases in the yield of green forage in a fertilizer experiment on a Río Piedras clay. No such increases were obtained with potash fertilizers.

3. Liming increased yields for the first cutting of kudzu only in a fertilizer-lime experiment on a heavy plastic Fajardo clay. Nitrogen was also of significant value in increasing forage yields and protein for the first cutting only. The second and third cuttings had no yield or protein increases that could be attributed to any fertilizer or lime treatment.

4. At Corozal, on a friable, acid Lares clay, kudzu did not respond to nitrogen, phosphorus, and potassium fertilizers. The response to liming was in protein content and then only in the second and third cuttings.

5. The use of nitrogen and lime is of value in establishing good productive stands of kudzu on very acid soils (pH below 5) of low fertility.

6. The effects of the use of borax and of magnesium oxide as minor-element fertilizers were negligible from the standpoint of yield and protein production.

RESUMEN

A continuación, se informan los efectos de los abonos y la cal sobre el rendimiento y contenido de proteína del Kudzu tropical, según se observaron en los experimentos que se detallan en el presente trabajo.

1. En un experimento, llevado a cabo en invernadero (green-house), los rendimientos del kudzu aumentaron, según se subió el pH en los terrenos encalados, resultando el mayor rendimiento en los terrenos con un pH de 7.5.

2. El nitrógeno y el fósforo produjeron resultados significativos en el rendimiento del forraje verde del kudzu, en un experimento con abonos en suelo Río Piedras arcilloso. Sin embargo, no se observó aumento alguno en los rendimientos en el mismo suelo, cuando se aplicaron abonos potásicos.

3. Las aplicaciones de cal aumentaron los rendimientos del primer corte de Kudzu sólo en un experimento combinado de aplicaciones de abonos y cal llevado a cabo en un suelo Fajardo pesado, plástico y arcilloso. El nitrógeno también fué de valor significativo para aumentar el rendimiento del forraje y su contenido de proteína, en cuanto al primer corte únicamente. Los cortes segundo y tercero no tuvieron aumentos en el rendi-

miento del forraje, ni en su contenido de proteína, que pudieran atribuirse a la aplicación de abono alguno o de la cal.

4. En Corozal, en un suelto y ácido arcilla Lares, el Kudzu no respondió a las aplicaciones de nitrógeno, fósforo y potasa. Reaccionó favorablemente, en cuanto al contenido de proteína, cuando se le aplicó cal al mismo suelo, pero sólo en los cortes segundo y tercero.

5. La aplicación de nitrógeno y cal a los terrenos muy ácidos y pobres, con un pH de menos de 5, ayuda a establecer buenas siembras de Kudzu.

6. Los compuestos de boro y el óxido de magnesio, usados como elementos menores en el abonamiento del Kudzu, no demostraron surtir efectos que pudieran reflejarse sobre los rendimientos y contenido de proteína del Kudzu.

LITERATURE CITED

1. Roberts, R. C. and party, Soil Survey of Puerto Rico, U.S.D.A. Series 1936, No. **9** Bur. of Plant Ind. in cooperation with Univ. P. R. Agric. Exp. Sta., 1942.
2. Riera, A. R., Laboratory recommendation of lime to an acid soil checks with expected pH changes, *J. Agr. Univ. P. R.* **30** 184–5 1946.
3. Samuels, G., and Landrau, P., Jr., The effects of fertilizer applications on the yields and nodulation of tropical kudzu, *Soil Sci. Soc. of Amer.* **16** 154–5 April 1952.
4. Smith, R. M. and Chandler, J. V., Tropical kudzu moves into Puerto Rico, *Crops and Soils*, pp. 12–14, March 1951.
5. Telford, E. A., and Childers, W. F., Federal Expt. Sta. in Puerto Rico, U.S.D.A. Office of Expt. Sta. Cir. No. **67**, 1947.

EFFECT OF DIFFERENT QUANTITIES OF VELVETBEAN GREEN MANURE ON CORN YIELDS IN PUERTO RICO

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INTRODUCTION

Velvetbeans *Stizolobium deeringianum*, a legume, when added to acid soils of Puerto Rico, both in the presence and in the absence of lime and phosphorus, gave higher significant yields of green manure than three other legumes tried: Crotalaria *Crotalaria striata*, cowpeas *Vigna sinensis*, and soybeans *Soja max*, Otootan variety (1)[2]. Green manure from velvetbeans, 4 tons of limestone, and 100 pounds of P_2O_5 as superphosphate, significantly increased the yields of sweetpotatoes and corn in two acid soils of Puerto Rico (2). A 30-month rotation sequence of two crops of the four above-mentioned legumes, one of sweetpotatoes, two of the legumes, and one of corn was studied from June 1944 to November 1947, inclusive, in both soils. The equivalent of 4.5 to 6 tons of green manure per acre was incorporated into each soil per crop of velvetbeans, or a total of 9 to 12 tons from the crops of velvetbeans, before planting sweetpotatoes and corn, respectively.

This paper reports data obtained on the effect on corn yields of velvetbean green manure when incorporated into the soil in smaller and in larger quantities than those previously used, either as a mulch or turned under. The work did not include a comparison between turning under the green manure or leaving it as a mulch.

EXPERIMENTAL PROCEDURE

The sites selected for the field work lie within the same general area where the previous work with legume and food crops was done (1, 2): Río Piedras in the north at 18° 24′ N. latitude and 63° 03′ W. longitude, and Mayagüez, 150 miles away to the west, at 18° 12′ N. latitude and 67° 09′ W. longitude. Two 1-acre fields of Fajardo clay were selected in the García Méndez farm in Río Piedras, and two of Catalina clay in the Las Ochenta farm at Mayagüez. Applications of superphosphate were made to the acid plots at the rate of 100 pounds of P_2O_5 per acre and of ground limestone at the rate of 4 tons per acre before the velvetbeans were planted.

For the field experiments four-tenths of an acre was selected at Río Piedras and two-tenths at Mayagüez. The fields were planted with velvetbeans following the contour lines and divided into plots one-hundredth of an

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[2] Numbers in parentheses refer to Literature Cited, p. 101.

acre in area. Adjacent areas were planted to velvetbeans to supply enough green manure for the differential treatments.

The velvetbean seeds were planted at a 6-inch distance within rows placed 1-foot apart. After the legume crop was harvested, the following treatments were used: Check; 5 and 10 tons of green manure per acre, respectively, at Mayagüez; and a fourth test with 25 tons of green manure per acre at Río Piedras. Six replicates were used at Mayagüez and nine at Río Piedras. At each location the green manure was left as a mulch in one field and turned under in a second.

Two crops of corn followed the velvetbean crop at Río Piedras and one at Mayagüez. The plots at Río Piedras were hoed to a depth of about 4 inches before planting the second corn crop. Seeds of the Mayorbela variety were planted in hills, 18-inch apart with a 3-foot distance between rows. Four seeds were placed in each hole and covered with soil. The germinated plants were thinned to two seedlings per hole. The corn plants were sprayed several times with 3 pounds of 50-percent DDT in 100 gallons of water per acre to control the caterpillar *Laphygma frugiperda*. A bait of phosphorus paste with corn flour was used for rat control. Each corn crop received an application of 240 pounds K_2O per acre as muriate of potash.

Surface soil samples were taken at a 6-inch depth from each plot used for each crop at Río Piedras after the second corn crop was harvested. Nitrogen, organic matter, and pH were determined on these soil samples.

RESULTS AND DISCUSSION

The rotation sequence, dates of planting and harvesting, and age of the velvetbeans and corn crops at Río Piedras and Mayagüez are reported in table 1. The mean yields of the corn crops and the least significant differences for the different levels of green manure mulched or turned under are reported in table 2.

The mean green weight for the crop of velvetbeans grown at Río Piedras was 4.5 tons to the acre. At Mayagüez the yield ranged from 0.7 to 5.2 tons to the acre with a mean of 2.8 tons. The Río Piedras crop was normal when compared to the previous four crops raised (1, 2) at the same general location. However, the Mayagüez crop was rather poor even when sufficient lime and phosphorus was supplied.

The analyses of the total sum of squared deviation of dry shelled corn yields for the two corn crops at Río Piedras and the one at Mayagüez are reported in table 3.

There was a highly significant difference between treatments for the corn crop in Catalina clay at Mayagüez; 5 tons of green manure notably increased the corn yields (table 2) when left as a mulch or turned under. The interaction between treatments and fields at Mayagüez was highly signifi-

cant; 10 tons of green manure turned under significantly increased the yield of corn, but no significant increase was obtained in the mulched field. Bonnet et al. (2) found significant responses in the yield of sweetpotatoes and corn in two other fields of Catalina clay when 9 tons of velvetbean green manure from two consecutive legume crops were applied with 4 tons of limestone and 100 lbs. P_2O_5 per acre.

TABLE 1.—*Rotation sequence, dates of planting and harvesting, and age of crops at Río Piedras and Mayagüez*

Crop	Crop in the rotation	Location	Date of planting	Date of harvesting	Age
					Days
First	Velvetbeans	Río Piedras	Dec. 4, 1947	Feb. 17–20, 1948	79
		Mayagüez	Apr. 30, 1948	Sept. 15, 1948	108
Second	Corn	Río Piedras	May 12–14, 1948	Aug. 18–19, 1948	96
		Mayagüez	Sept. 28, 1948	Dec. 22, 1948	86
Third	do.	Río Piedras	Dec. 9–10, 1948	Mar. 28, 1949	107

TABLE 2.—*Mean yields in hundredweights to the acre and least significant differences for dry shelled corn at different levels of green manure, mulched or turned under in different fields*

Treatment	Mayagüez crop 1		Río Piedras			
			Crop 1		Crop 2	
	Mulched	Turned under	Mulched	Turned under	Mulched	Turned under
Check, no green manure	4.0	1.5	14.3	22.1	12.7	11.4
5 tons green manure	15.6	16.6	14.6	21.0	12.2	12.4
10 tons green manure	16.0	20.6	16.0	23.2	13.6	10.4
25 tons green manure	—	—	17.9	23.1	14.6	13.5
L.S.D. between means of two treatments:						
at 5-percent point	2.9	2.4	4.7	4.0	4.8	3.7
at 1-percent point	4.2	4.2	6.4	5.4	6.5	5.1

There was no significant difference between treatments for the two corn crops in Fajardo clay at Río Piedras. The soil content of 0.23 percent of N (table 4) was sufficient to produce the maximum corn yield obtained. The mean organic-matter content of this soil was 3.4 percent. Bonnet et al. (2) found significant responses in the yield of sweetpotatoes and corn in two other fields of the acid Fajardo clay when 12 tons of velvetbean green manure from two consecutive legume crops were applied with 4 tons of limestone and 100 lbs. P_2O_5 per acre. That field contained 0.17 percent of

nitrogen or 0.06 percent less than the field of Fajardo clay where the velvetbean green manure did not significantly increase the corn yields. The organic-matter content of this soil was about half of that, or 1.7 percent.

TABLE 3.—*Analyses of the total sum of squared deviation for dry shelled corn yields*

Crop No.	Place	Source of variation	Degrees of freedom	Sum of squares	Variance	*F* values
1	Río Piedras	Total	71	2,054.76	.....	.....
		Blocks	16	361.76	.....	.....
		Fields	1	802.47	.....	.....
		Treatments	3	83.07	27.69	1.68
		Treatments × fields	3	17.93	5.98	.36
		Error	48	789.53	16.45	.....
1	Mayagüez	Total	35	1,942.22	.....	.....
		Blocks	10	60.63	.....	.....
		Fields	1	9.51	.....	.....
		Treatments	2	1,683.98	841.99	175.40[1]
		Treatments × fields	2	92.16	46.08	9.60[1]
		Error	20	95.94	4.80	.....
2	Río Piedras	Total	70	2,674.62	.....	.....
		Blocks	16	1,675.94	.....	.....
		Fields	1	31.30	.....	.....
		Treatments	3	47.53	15.80	.83
		Treatments × fields	3	20.54	6.80	.36
		Error	47	899.40	19.14	.....

[1] Highly significant.

TABLE 4.—*Chemical data on the surface-soil samples taken at Río Piedras 13 months after the treatment differentials were established and after the second corn crop was harvested*

Treatment	Mulched				Turned under			
	pH	Total nitrogen	Organic matter	C/N ratio	pH	Total nitrogen	Organic matter	C/N ratio
		Percent	*Percent*			*Percent*	*Percent*	
Check, no green manure	5.0	0.23	3.9	10.1	4.9	0.24	2.9	7.0
5 tons green manure	4.9	.16	3.8	17.7	5.0	.25	3.2	7.4
10 tons green manure	5.1	.17	3.6	18.9	5.4	.25	2.9	6.6
25 tons green manure	4.9	.21	3.9	15.9	5.0	.24	3.5	8.4

The second corn crop was planted after leaving the land fallow for a 4-month period (table 1). This crop was scheduled to be planted early after harvesting the first one, but the continuous rains throughout the fall caused a considerable delay. The second crop was intended to measure the residual effects, if any, of the additions of green manure before planting the first

corn crop. The second crop suffered a heavy reduction in the number of plants from a severe rat attack. Instead of 160 plants in each plot, the population varied widely from a minimum of 20 to 50 to a maximum of 131 to 152. A covariance analysis was made to correct yield variations attributable to stand but the reduction in sum of squares for treatments was not significant. The residual effect of the green manure did not raise the yields of the second corn crop.

The mean values for the soil samples taken at a 6-inch depth in the acid Fajardo clay at Río Piedras, including pH, nitrogen, organic matter, carbon-nitrogen ratio, representative of the mulched and turned-under treatments, and the least significant differences, are reported in table 4. In general, no significant differences were obtained between each of the above mean values for the treatments, but the nitrogen content was significantly higher in the check plots than in the plots mulched with 5 or 10 tons of green manure. The active microorganisms used about 0.07 percent of the soil nitrogen in decomposing the 5 and 10 tons of green manure but with the 25 tons there was no apparent change in the soil nitrogen.

SUMMARY

Different levels of a leguminous green manure from velvetbeans, either left as a mulch or turned under, were added to two acid soils in Río Piedras and Mayagüez, Puerto Rico, that received 4 tons of ground limestone and 100 pounds P_2O_5 per acre. The objective was to study the effect of the manure upon the yield of corn fertilized with 240 pounds of K_2O per acre.

Five tons of the green manure increased the corn yields in Catalina clay at Mayagüez whether left as a mulch or turned under. However, 10 tons increased the yields when turned under but not when left as a mulch.

There was no significant difference in corn yields in acid Fajardo clay at Río Piedras whether 5, 10, and 25 tons of green manure were used. But significant yield responses of sweetpotatoes and corn were obtained before (2) in two other fields of this soil. The difference in behavior is explained on the basis of the higher nitrogen and organic-content of the soil in the field where responses were not obtained.

The residual effect of the green manure did not raise the yields of a second corn crop at Río Piedras.

RESUMEN

A dos suelos ácidos de Puerto Rico, a los cuales se les había añadido cal y ácido fosfórico (P_2O_5), a razón de 4 toneladas y 100 libras por acre, respectivamente, también se les añadió distintos niveles de un abono verde de habichuelas terciopelo. El abono verde se enterró en un campo y se dejó como capa mullidora (mulch) en otro campo.

El objetivo del trabajo fué estudiar los efectos del abono verde sobre los rendimientos del maíz, el cual había sido abonado con 240 libras de potasa (K_2O) por acre.

Cinco toneladas del abono verde, indistintamente, aumentaron los rendimientos del maíz en una arcilla Catalina en Mayagüez, cuando se enterró o se usó como capa mullidora.

Sin embargo, 10 toneladas de la misma clase de abono verde sólo aumentó los rendimientos cuando se enterró con arado, siendo desatendibles los efectos al dejarse como capa mullidora.

No hubo diferencias significativas en los rendimientos del maíz en la arcilla ácida Fajardo en Río Piedras, aún usando 5, 10 y 25 toneladas del abono verde. Sin embargo, anteriormente se habían registrado aumentos en los rendimientos de batatas y maíz, en dos parcelas del mismo tipo de suelo en el mismo sitio, lo que da a entender que el contenido de nitrógeno y materia orgánica en el terreno habían llegado ya a su estado óptimo, antes de establecer el experimento.

El efecto residual del abono verde, tampoco aumentó los rendimientos de una segunda cosecha de maíz que se sembró en el mismo sitio en Río Piedras.

LITERATURE CITED

1. Bonnet, J. A., Telford, E. A., Mariota, F., and Tirado-Sulsona, P., Effect of lime and phosphorus on the yield of four leguminosae in two acid soils of Puerto Rico, *J. Agr. Univ. P. R.* **29**(2) 47–56, 1945.
2. Bonnet, J. A., Tirado-Sulsona, P., and Abruña, F., Effect of lime-phosphorus and green manure on sweetpotatoes and corn grown in acid soils, *J. Agr. Univ. P. R.* **31**(4) 303–321, 1947.